DOCUMENT RESUME

ED 322 399 CE 055 593

AUTHOR Ritz, John M.; And Others
TITLE Resources in Technology 4.
INSTITUTION International Technology Education Association, Reston, VA.
PUB DATE 87
NOTE 69p.; For related volumes, see CE 055 590-595.
AVAILABLE FROM International Technology Education Association, 1914 Association Drive, Reston, VA 22091-1502 ($6.50 members, $7.50 nonmembers; six-volume set: $35.00 members, $37.50 nonmembers).
PUB TYPE Collected Works - General (020) -- Guides - Classroom Use - Materials (For Learner) (051)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Ceramics; *Communications Satellites; Engineering Technology; Futures (of Society); *Industrial Arts; Learning Motivation; Occupational Information; Postsecondary Education; *Printing; Science and Society; Secondary Education; Teacher Influence; *Technological Advancement; Technological Literacy; *Transportation

ABSTRACT

This document--intended to help technology education teachers plan their classroom curriculum for secondary school and college students--contains units on satellite communication, the nature and properties of engineering materials, careers in technology, new developments in printing, composite materials, ceramics, ceramic materials, and personal rapid transit. The sociocultural impact of each of those topics and its relationship to the common elements of technological systems are covered in each unit. Units also typically include narrative information, line illustrations, photographs, a glossary of technical terms, an audiovisual aid, a construction activity, examples of how math and science can be used to support the students' construction activities and provide the motivation for students to make the connections between technical education and math and science, a student quiz, possible student outcomes, and references. (CML)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

ED322399

Resources in Technology

4

U.S. DEPARTMENT OF EDUCATION
Office of Educational Research and Improvement
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)

☑ This document has been reproduced as received from the person or organization originating it

☐ Minor changes have been made to improve reproduction quality

• Points of view or opinions stated in this document do not necessarily represent official OERI position or policy

"PERMISSION TO REPRODUCE THIS MATERIAL IN MICROFICHE ONLY HAS BEEN GRANTED BY

TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

CE055593

International Technology Education Association

BEST COPY AVAILABLE

1 Satellite Communication
9 Nature and Properties of Engineering Materials
17 Careers In Technology
25 New Developments in Printing
33 Composite Materials
41 Check the Ceramics, Please!
49 Ceramic Materials
57 PRT: The Way To Go!

Contributing Authors
Tidewater Technology Associates
Members:
John M. Ritz
Paul L. Cummings
Walter F. Deal, III
Martin M. Fay
W. Fred Hadley
James A. Jacobs

Note: These activities may be reproduced without permission for use in the classroom.
© ITEA, 1987

INTERNATIONAL TECHNOLOGY EDUCATION ASSOCIATION

SATELLITE COMMUNICATION

The phrase "live via satellite" has become an everyday phrase on television in the developed world. With the launching of the Soviet satellite Sputnik I (meaning fellow traveler), on October 4, 1957, a new era of technological development was born. Developed societies were thrust into the space age. Through research and development efforts generally using satellites, new means of communication technology have evolved.

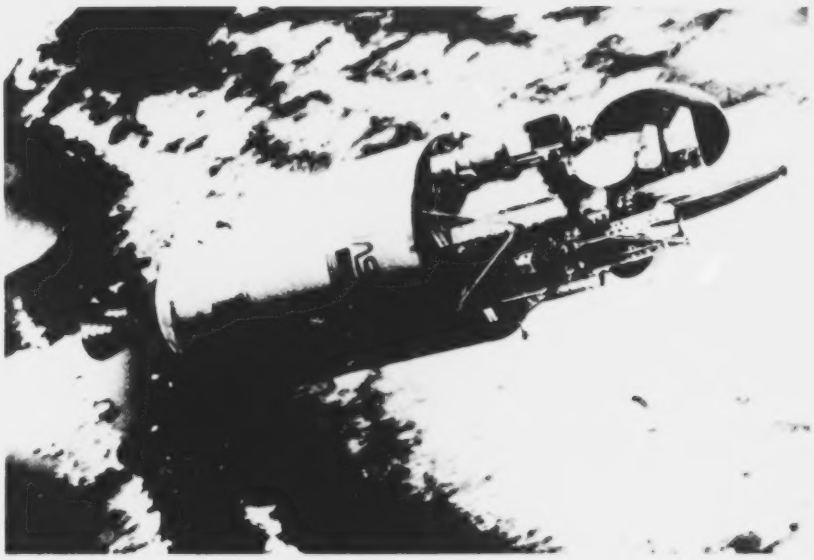
As with the development of so many modern high impact technological developments, research during and following World War II led to the development of communication satellites. The first proposal for using satellites in an advanced communication system was delivered by Arthur C. Clark in 1945 (Gatland, 1981, p. 86). However, there was no way to boost a satellite into orbit at that time. Other early experimentation conducted by the U.S. Army in 1951 confirmed that radio transmissions could be made through outer space. Its experiment involved transmitting radio waves to the moon, a natural satellite, and bouncing them back to earth. But it was not until Sputnik I that an artificial satellite was used as a radio beacon to transfer information.

A communication satellite is a spacecraft that can be used to extend the limits of distance and access to world information. The integration of space, electronic, and information technologies has made it possible.

Two types of satellite systems have been developed: passive and active. In the early years of research, tests were conducted using each type. Passive satellites act as reflectors of microwave transmissions from the earth. They are launched into a low orbit (a few hundred miles) and information can be reflected off of them when they are near the horizon.

Early satellites of this type included the Echo series, launched in the 60's. Echo I was a large balloon, 100 feet in diameter, made of aluminum-coated Mylar. It proved that two-way telephone conversations could be reflected across the U.S.

Today all satellites fall into the active transmission type. Their electronic circuitry will receive a signal, amplify it, and retransmit it back to earth. Early researchers realized that this was what was needed—satellites that would work like telephone microwave relay towers in space.



An artist's conception of the Orbital Transfer Vehicle that would ferry payloads in space from one orbit to another

The first active communication satellite was Telstar. It was popularized in the early 1960's when a record was produced describing its abilities. Telstar enabled television broadcasts to be seen in Britain, France, and the U.S. simultaneously. Some cite this event as the birth of the global village (Gatland, 1981, p. 87).

Most active communication satellites are placed in a much higher orbit than passive satellites. This is because at a low orbit they could only transmit information when they were within the horizon of two transmitting/receiving stations. At a low orbit this would amount to only 15 to 20 minutes of usefulness on each satellite pass. Transmitters/receivers would also need to redirect themselves to focus on the satellite while it was in range. It was estimated that 30 to 40 such low orbit satellites would be required to have continuous world-wide communications (*Man on the Move*, 1968, p. 132).

Instead most communication satellites are placed into a synchronous orbit—22,300 miles above the earth's equator. In such an orbit they travel at the same speed the earth rotates. Therefore, they appear to be stationary in relation to locations on the Earth. With this altitude and orbit, it takes only three synchronous satellites to set up a global communications network. Figure 1 illustrates the concept of synchronous orbits. Reconnaissance communication satellites which gather information on world conditions (military build-ups, cartography, agriculture, pollution, etc.) continue to travel in low non-synchronous orbits so they can span regions of the globe and gather information in a closer view of the earth. This is also illustrated in Figure 1.

The first communication satellites to be put into synchronous orbit were the Syncon series began in 1963. These satellites were used for experimental television broadcasts. In 1964 portions of the Olympics were broadcast live from Japan. From these experiments the value of communication satellites was learned. Consequently ventures to industrialize space technology began. Intelsat (International Telecommunications Satellite Organization) was formed in 1964 by several nations. What followed was the launching of a number of active, synchronous satellites (21 operational by 1977) that could be

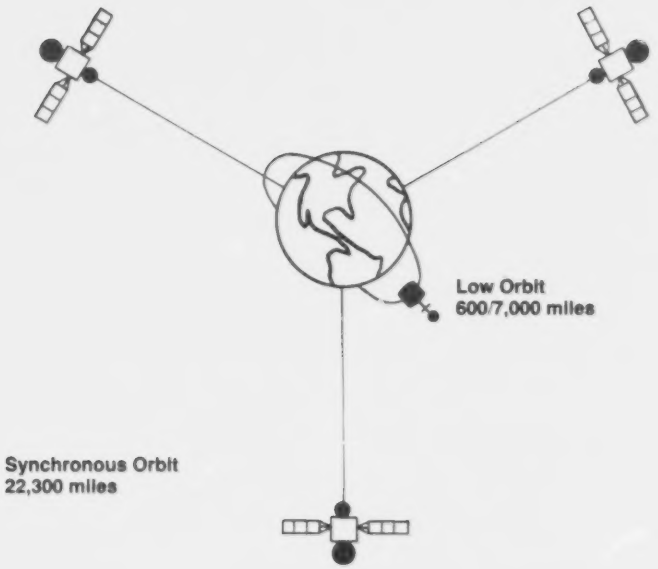


FIGURE 1

Low and synchronous orbits of satellites.

shared by member/nations for telephone and television transmissions. The original cost per circuit per month was $30,000 in 1965. By 1977 the price per circuit per month had dropped to $1,140 (Gatland, 1981, p. 88).

Since early communication satellites were under control of the government, private companies could only lease circuits for commercial use. In 1972 the FCC opened the way for domestic ventures when it permitted companies to own their own satellites (Singleton, 1983, p. 79). Today we have Westar (Western Union), Consat (AT&T), and Satcom (RCA) to mention a few private satellite systems.

A communication satellite integrates electronic, space, and information technologies. When a station or network decides what it wants to broadcast, it must integrate these technologies to have it happen. While standard filming procedures are followed at the scene of the event, the technologies used for transmission differ.

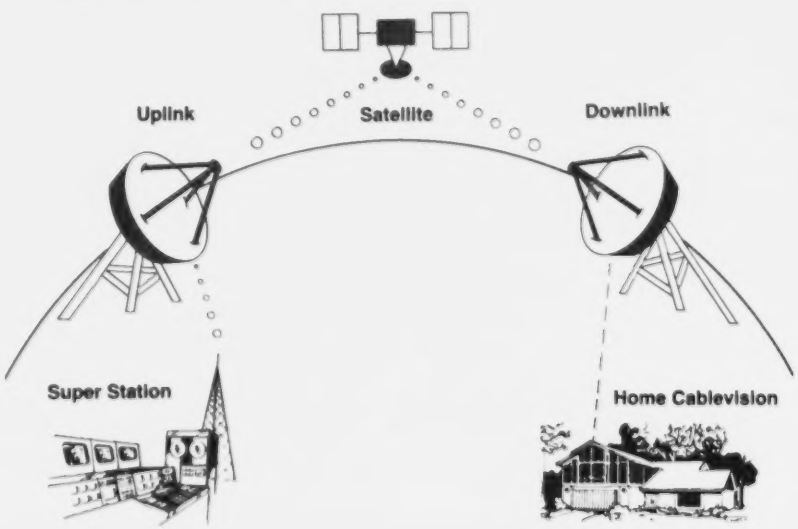
Figure 2 illustrates the operation of a typical satellite television transmission. The satellite receives a signal from the ground station. This is referred to as the up-link. On the satellite the signals are received on one of many circuits (depending on the frequency of the transmission), amplified, and sent back to earth to a receiver. This is called the down-link. Typically satellites have 12 to 24 transponders (Trocki, 1985, p. 5).

The signals can be received by viewers in one of many ways. A local station may pick up the signal, re-transmit it, and you may receive it at home on a fixed antenna. A cable system may pick up the transmission and re-transmit it over its cable lines. Finally you may have a dish in your yard and pick up the broadcast direct from the satellite. This is referred to as direct broadcast satellite (DBS) or television receive-only (TVRO).

There are several economic reasons why companies have invested in satellite communication systems. To broadcast a one hour coast-to-coast television program using the telephone system costs approximately $2,000. Using a satellite the same broadcast costs $400. Similar cost reductions also apply to voice and data transmissions (Singleton, 1983, p. 82).

FIGURE 2

Operation of a typical satellite television transmission.



Social/Cultural Impacts

From the first launching of a communication satellite in the 1960's, our world has become a "global village" in 20 short years. Today we can watch television and instantly find out what is going on throughout the world. During the recent kidnapping crisis in Lebanon, we could see the hostages as they were released—half way around the world.

Besides providing instantaneous news coverage, satellite communication has also effected television entertainment. Cable television was making slow progress as an alternative to antenna reception. Only consumers in areas that had chronically poor reception from metropolitan broadcasts were eager purchasers of cable services. However when HBO (Home Box Office) began relaying movies via satellite to commercial cable companies, cable television became a profitable venture.

In addition to cable television, satellites have also made it possible for "super stations" to become a reality. Today we have such stations in Chicago and Atlanta. WTBS (Turner Broadcasting) in Atlanta provides a super station that transmits news, entertainment, and Atlanta Braves baseball over a satellite which is available in much of the U.S. via cable. Ted Turner has also proposed "beaming" his super station to Europe, via satellite, later this year.

Another development that has resulted from satellite tv has been DBTV (direct broadcast television). With FCC deregulation, consumers can own receiver dishes. These are beginning to decorate the lawns of Americans' homes in both rural and metropolitan areas. Advertised commercial prices

are now under $2,500. With an adjustable dish, the public is capable of receiving over 100 uncensored channels of information.

With cable and DBTV programming increasing to meet the diverse wants of today's consumers, we have such channels as DIS (Disney Channel); ESPN (Sports); BFT (Black Entertainment); MTV (concerts); SHOW and CBN, (Christian broadcasting) to mention but a very few. The satellite has truly made its impact on society via tv broadcasts.

Telephone hook-ups with satellites are also replacing ground and microwave transmissions. This is particularly true for overseas and ship-to-shore conversations. With the international development of so many corporations, world-wide communication channels are needed. Satellite communications make this cheaper and provide more channels for information access.

Another area where satellite communication is being used to better the world is in reconnaissance. The first use of communications satellites for reconnaissance was by the military. From a few hundred miles above the earths surface, satellites can take continuous pictures of the earth and, through magnification, observe military installations and maneuvers.

Besides use in national defense, satellites also communicate other information that has bettered our planet and lives. Today satellites aid in cartography or map-making. From their view above, they can flash back pictures that enable us to correct and update maps of our country and to improve those of desolate parts of the world. They are also useful for charting undersea reefs, coastal erosion, and planning for the construction of railways, roads, and irrigation channels.

Agriculture is another area where satellites have contributed to the betterment of humankind. By viewing crops from outer space, predictions can be made of expected yields. This aids in plans to reduce world hunger. The fertility of regions of the earth can also be determined by infra-red photographs. With this information nations can better plan for food production. Another use of satellite observation in agriculture is to detect and follow crop disease and insect infestation. Through this monitoring, crop disease can be minimized and yields increased.

Range land monitoring has also advanced through information communicated via satellites. This information is particularly useful to developing counties in desert regions. Grazing rotation and land management can stop the spread of desert land. This information can also be used to plan for improvements such as irrigation and seeding.

Communication satellites are being used in forestry in ways similar to those in agriculture. The volume of timber in areas can be estimated and consequences of over-harvesting can be predicted. Fire damage in remote areas can also be assessed.

By the use of satellites, our oceans can also be better monitored. Automatic buoys measure water temperatures, salinity and wave heights and transmit this information directly to satellites for re-transmission and use at ground stations. They can also be used by fisheries in locating thermal boundaries which in turn locate fish congregations. Other uses of satellites in the oceans include the spotting of icebergs and the direct linkage of ships to aid in navigation and communication to ports. Navsat is a system where ships can determine their exact location from radio waves transmitted from satellites in a synchronous orbit. These same satellites can be used for telephone communication to ports throughout the world. By redirecting ships, while at sea, companies can save days and money by changing the destination of its ships. A tanker loaded with oil that may reach a port a day earlier could save the company up to $15,000.

Another use of the satellites monitoring the oceans is in saving lives. The Coast Guard has just recommended that the U.S. ships should carry emergency beacons that would communicate—via satellites—their exact locations. Many times lives are lost because downed ships cannot be found quickly.

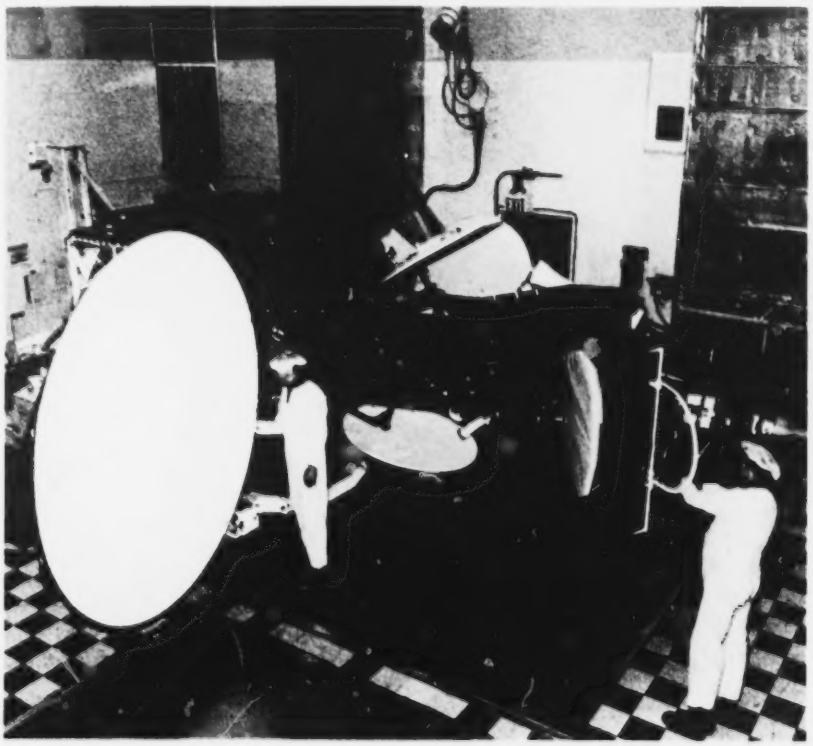
Satellites are also used to monitor both oil and air pollution. Some times tanker captains wash out their tanks at sea. This causes an oil slick that pollutes our beaches and injures wildlife. By satellite, this pollution can be detected and the culprits more easily traced. In their study of air pollution scientists use satellite information to determine the centers of pollution and the means to break up the pollutants so they cause less harm to our environment.

Another major industrial use of satellites is in gathering information on mineral and oil deposits. Minerals can be identified by the color of rock. The formation of land masses suggest where oil and natural gas deposits might be located.

Communication satellites are also used by meteorologists to predict the weather. Each day we can watch our local news on television and see the weather maps for the nation and our local areas. With these, meteorologists predict the weather. Major storms are also tracked so the public can be warned to seek shelter to avoid natural disasters.

Wildlife can also be tagged, then monitored by satellite to observe migration patterns. This can help scientists guard endangered species and tell us more about the animals and fish that share the planet with us.

As the above examples have shown communication satellites do provide much more than television coverage and telephone conversations. These spinoffs of space technology have bettered the life of the human species. In the near future satellites will probably contribute more to better humankind.



Cape Canaveral technicians complete the checkout of the Intelsat V-A antenna systems. Launched in March, 1985, this is the largest and highest capacity commercial communications satellite built to date.

Forecasts

As with most technologies, scientists and researchers continue to make improvements in hardware so that profit and product will be improved. Within the realm of satellite communications, several trends will shape the near future. New satellites will have transponders more powerful than present ones. This means stronger signals will be directed back to earth using less power. This results in improved transmission.

Satellites will also have a greater life expectancy. Improvements in solar cells and batteries will extend the time that they may be used to receive and retransmit information. Current missions by the space shuttle also prove that satellites can be serviced and maintained in outer space. This will also increase the life expectancy of communication satellites.

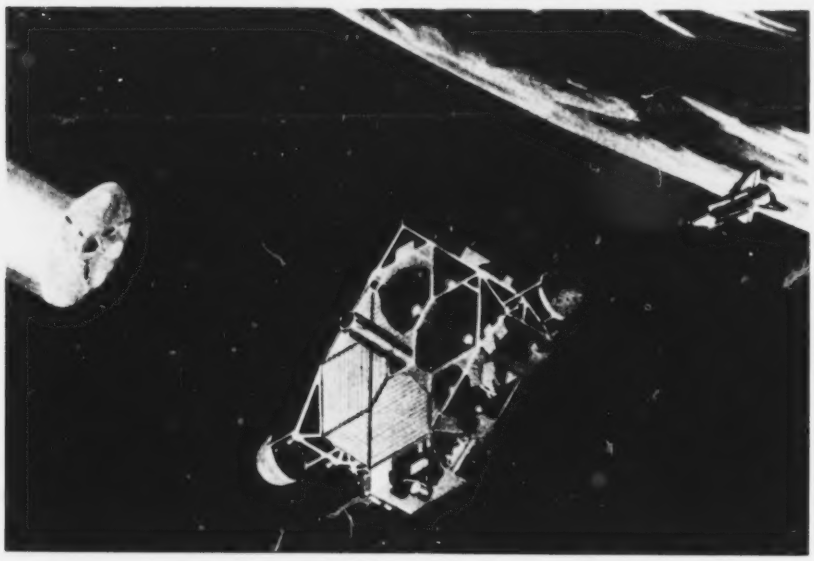
Although improvements are expected in the hardware of communication satellites, regulatory issues cloud the future. With estimates that 25% of U.S. voice traffic (telephone calls) by the year 2000 will be handled by satellite, additional space craft will need to be launched (Gatland, 1981, p. 94). However the "parking band" available 22,300 miles above the U.S. is limited. To prevent interference, the FCC has allotted satellite parking slots four degrees apart—1,800 miles (Singleton, 1983, p. 84). This means there are only 15 orbiting slots over the U.S. Currently 12 are in use (Gatland, 1981, p. 94).

With new technologies, it is hoped that the satellites will be able to operate one degree apart. This will provide 60 slots across the U.S. If this plan does not prove feasible, space station satellites could prove to be the answer. If the communication stations could be assembled in outer space, they could be larger and provide more transponders and circuits for domestic use. Maintenance could also be improved and the structure could be upgraded over their life span for improved access to world information.

DBTV (direct broadcast television) has also created other issues that must be dealt with in space technology. Today direct broadcast provides increased entertainment, without restrictions in programming, to people throughout the world. Backyard dishes are increasing throughout the U.S. In developing countries, DBTV provides remote villages on programs dealing with farming, hygiene, and medical problems. In the '70s teachers in rural Appalachia used it for teacher conferences.

However in many developing and Communist countries, political leaders want control over direct broadcast satellites. They fear that Western propaganda will threaten their political and cultural stability. These and many other issues need to be resolved so that satellite communications can be available to all populations.

"Live via satellite" is the method of modern communication technology. In 28 years from Sputnik I, we have become one community—a global village. Many new jobs have been created in this form of high technology. Today space technology is a billion dollar business. It has created new jobs for scientists, engineers, technicians, and craftspersons. All of these new jobs rely on an understanding of science, technology, and mathematics. The next section of this article will explore this.



An artist's concept of the Orbital Maneuvering Vehicle that is proposed for launch by 1990. It would supplement the present space transportation system, the heart of which is the space shuttle.

Math/ Science/ Technology

The previous sections of this article have dealt with the social, cultural, and technological impact of satellites, particularly communication satellites. Considering the vastness of the technology that is necessary to launch and deploy a satellite it can "boggle" your mind. Conceptually, we are concerned with several fundamental principles. These are: (1) designing and making the launch vehicle, (2) identifying the purpose of the satellite, (3) designing and making the satellite, and (4) placing the satellite in the proper "orbit."

The physical laws of Newton, Kepler, and discoveries of Marconi and Clarke are but a few of the important scientific principles that make the satellite a reality. The science of metals, fuels, flight, and mathematics all play a major role in the design, development, and deployment of satellites. If you will remember, Newton is noted for the laws of *universal gravitation* and his formulation of the concept of force expressed in three laws of motion.

Johannes Kepler, a German astronomer, formulated three laws that described the motions of the planets in the solar system. They may be summarized as: (1) each planet orbits the sun in an *ellipse* of which the sun is at one end of the focus; (2) the line between a planet and the sun sweeps out equal areas in equal times, thus a planet moves faster when it is closer to the sun than when it is farther away; and (3) the square of the time taken by a planet to orbit the sun is proportional to the cube of the mean distance from the sun.

The primary purpose of a satellite is communication. Guglielmo Marconi, an Italian inventor and physicist, is noted for his work in radio waves and communication. His discoveries led to the development of the wireless telegraph during the late 1880's. The invention and development of the wireless communication opened new frontiers in communication.

Barely 50 years later it was not only possible to send messages by wireless telegraphy, it was also possible to send voice transmission, and even video signals. Thus, in the brief period of time since the invention of radio waves it is now possible to have real-time communication on a global scale. That is what we now call live via satellite in sound and living color!

Think for a minute . . . when you throw a rock up into the air. What happens? Naturally, it falls back to the earth!

Why is explained in Newton's laws about gravity. However, if it were possible to throw the rock "hard enough," that is with enough force, we could actually put it into orbit! With a little more force, we could

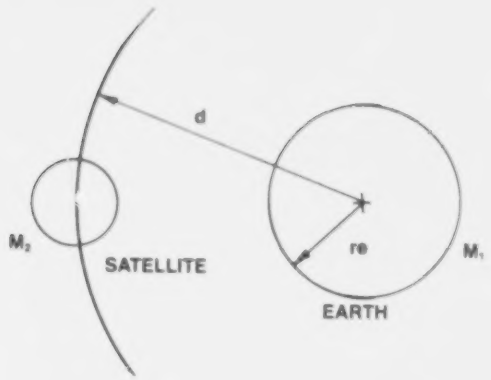


FIGURE 3

Force of gravitation between the earth and an object some distance above the earth. M1 is the Earth and M2 represents a satellite.

cause the rock to assume an elipitical orbit . . . with even more force, we could send the rock into "outer space" on a continuous journey to the planet Mars and beyond. In reality our space programs have gone through the similar developmental process. A bit of an over-simplification but the concept is there.

Newton's law of universal gravitation states that the attractive forces *(F)* between two bodies' masses, (e.g., the earth and moon or earth and a satellite, M_1 and M_2 separated by distance *(d)*) may be mathematically defined by:

$$F_{grav} = GM_1M_2/d^2$$ (gravitational force)

Where:

$G = (6.70 \times 10^{-11}\ Nm^2/kg^{-2})$ (universal gravitational constant)

The symbol (G) is the universal gravitational constant. It is necessary to understand this and other concepts to be able to place a satellite in orbit.

In further examining the forces acting on a satellite we find that we have forces "pushing" the satellite outwards—called centrifugal force and forces "pulling" the satellite back to earth—called centripetal force. In theory, if we were to propel an object, a satellite, at the correct speed, distance, and angle relative to the earth, we could "suspend" that object over the earth in orbit. The relative position to the earth would change insignificantly. This is called a geostationary, geosynchronous, or synchronous orbit.

Centripetal force may be thought of as the force or tension acting on a string that is attached to a ball that we may swing around in a circle.

The centrifugal force may be thought of as the force that is keeping the ball suspended at the end of the string. As long as the downward acceleration or gravity (g) is equal to or less than the inward centripetal acceleration or force the ball will be "suspended" in its "orbit" as we swing it around in a circle.

For example, if you were to attach a piece of string measuring one meter to a typical tennis ball and swing it in a circle over your head, what would be the minimum speed (velocity) necessary to keep the ball in orbit? To solve this problem, we would determine the centripetal acceleration.

$$\frac{v^2}{r} = g$$

$$v = \sqrt{rg} = \sqrt{(1.0m)(9.8\ m/s_2)} = 3.1\ m/s$$

Where:

v = velocity of the tennis ball
r = radius created by the string
g = acceleration of gravity (also 32 ft/sec²)

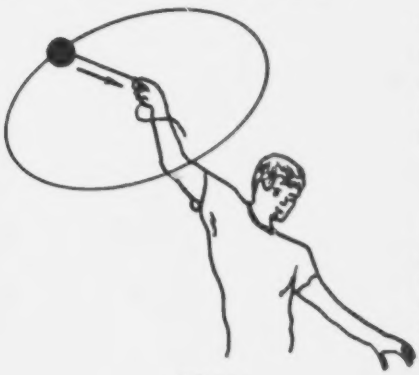


FIGURE 4

Centripetal force exerted on an orbiting object.

Changing this value into uniform circular motion, the ball as it travels in a circle will travel a distance of $2\pi r$ per revolution, which is the circumference of the circle. Speed or velocity is a relationship between distance travel in a given amount of time. This can be expressed as:

$$v = \frac{\text{distance}}{\text{time}} = \frac{2\pi r}{T}$$

In the example using the ball and the string, we can determine the time to make one revolution by:

$$T = \frac{(2\pi)(1.0\ m)}{(3.1 m/s)} = 2.0\ \text{seconds}$$

In discussing satellites in geosynchronous orbit, two terms have been described (centrifugal and centripetal forces) that relate why satellites stay in orbit. Near the earth the gravitational force acting on something, a person or object, of a specified mass—m—is its weight—w.

$$w = mg$$

The symbol g represents the acceleration of gravity at the location of the object and is expressed as 9.8 meters/sec² or 32 feet/sec². By definition a Newton may be defined as the force that can cause a mass of one kilogram to achieve an acceleration of 1 meter/sec².

For a uniform circular motion or orbit around the earth this force must provide the object with the centripetal force:

$$F_c = \frac{mv^2}{r}$$

Where:

F_c = centripetal force
m = mass of the object
v^2 = velocity of the object
r = radius (distance) between the center of the earth and center of the object

It is important to note that as the distance between the earth and the satellite increases the speed or velocity of the satellite decreases. This is because the acceleration of gravity (g) is proportional to the square of the distance (r) from the center of the earth. If we were to let g_o be the value of g at the earth's surface, then at the radius r

$$g = \left(\frac{r_e}{r}\right)^2 g_o$$

In restating the equation and solving for the satellite speed at radius, r, we find that:

$$v = \sqrt{rg} = \sqrt{\frac{r_e^2 g_o}{r}}$$

Orbit of earth satellite.

We can use the formulas above to illustrate an orbit just above the earth's surface, however, it will be a "random" orbit without any concern as to the where the satellite will be above the earth.

$$v_o = \sqrt{r_e g_o}$$
$$= \sqrt{(6.4 \times 10^6 m)(9.8\ m/s^2)}$$
$$= 7.9 \times 10^3 m/s$$

We should realize that the scientific world "thinks" in terms of metric units of measure. The illustrations that are shown are in the metric system. Noting that 7.9×10^3 meters per second is the velocity of the satellite and we may convert that value to the

American system of measurement by using a conversion constant of 1.6 km per mile

$$\frac{(7.9 \times 10^3)}{1000} \text{ (60 seconds) (60 minutes)} = 28{,}440 \text{ km/hr}$$

converting to miles per hour

$$\frac{28{,}440 \text{ km/hr}}{1.6 \text{ km/mile}} = 17{,}775 \text{ mph}$$

Geostationary orbits are a significant aspect of communication satellites. Basically, the satellite rotates with the earth at the same relative speed. Geo meaning "earth" and synchronous meaning "acting or moving together" may be defined mathematically by $T = 2\pi r/v$. And

$$v = \frac{2\pi r}{T}$$

Where:

v = velocity
r = radius
T = 1 day or 86,400 seconds

Thus, a geostationary satellite stays in the same relative position over the earth and is available for uplink and downlink communication activities 24 hours a day. Elaborate tracking systems are not required on a continuous basis as the case was with earlier satellites that travelled across the horizon and were only accessible for certain periods during the day.

The altitude of a satellite in synchronous orbit can be determined by combining two previously listed formulas thus eliminating the velocity and finding the difference between the radius of the earth and the radius of the satellite.

Following the simplification of the formulas:

$$\frac{2\pi r}{T} = \sqrt{\frac{r_e^2 g_o}{r}}$$

$$\frac{4\pi^2 r^2}{T^2} = \frac{r_e^2 g_o}{r}$$

$$r^3 = \frac{r_e^2 g_o T^2}{4\pi^2}$$

Substituting in some values into the equations, we can see the relative distance between the center of the earth and the satellite.

$$r = \sqrt[3]{\frac{r_e^2 g_o T^2}{4\pi^2}}$$

$$= \sqrt[3]{\frac{(6.4 \times 10^6 \text{m})^2 (9.8 \text{ m/s}^2)(8.64 \times 10^4 \text{s})^2}{4\pi^2}}$$

$$= \sqrt{759 \times 10^{20}} \text{m}$$

$$= \sqrt{75.9 \times 10^{21}} \text{m}$$

$$= 4.23 \times 10^7 \text{ meters}$$

However, it is more useful to state the distance or altitude of the satellite from the surface of the earth. That can easily be found by subtracting the radius of the earth r_e from the radius to the satellite r to arrive at the altitude h.

$$h = r - r_e$$
$$= 4.23 \times 10^7 \text{ m} - 6.4 \times 10^6 \text{ m}$$
$$= 35.9 \times 10^6 \text{ meters}$$

Converting meters to miles:

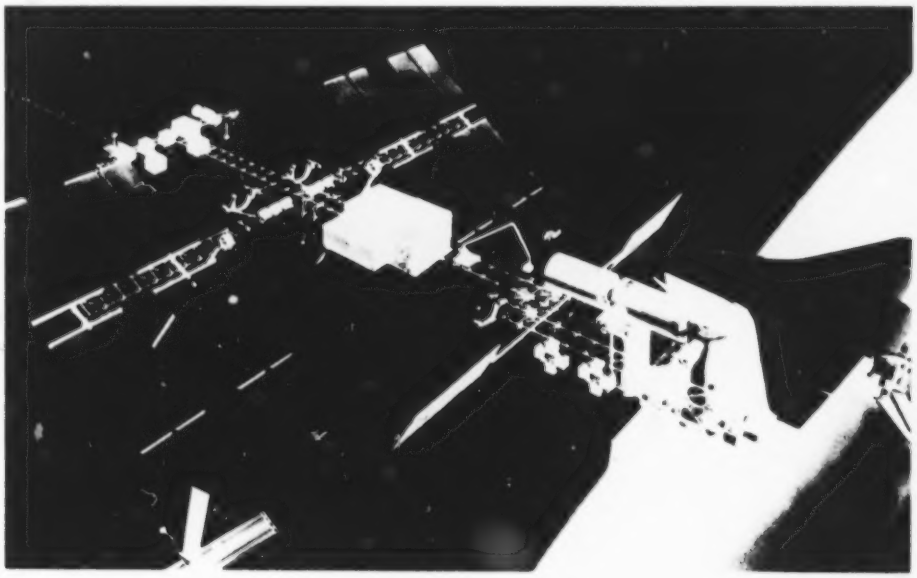
$$\frac{35.9 \times 10^6}{1.6 \text{ mile/km} \quad 1000} = 22.437 \times 10^3 \text{ miles}$$

Summarizing several of the major points, that have been discussed, we find that placing a satellite into orbit is a large task that involves a lot of planning and calculation. The satellite must be launched at the correct speed or velocity and deployed at the appropriate altitude. If not, then there are several possibilities. It will fall back to earth and crash, assume an eliptical orbit, or continue on into space. It is therefore necessary to insure that all calculations are correct and accurate.

The illustrations that have been presented are but a small aspect of the calculations necessary to "place" a satellite into orbit. When considering a synchronous orbit we must also consider the geographical location over which we want the satellite to be "stationary." The teams of men and women involved in such a project are engineers, physicists, mathematicians, systems analysts, and the like. There are many other occupations, trades, and professions involved in such a project. You may wish to explore further information on space and communication technology. Information on such topics are available from your library, National Aeronautics and Space Administration (NASA), communication companies such as American Telephone and Telegraph (AT&T), as well as many other companies.

FIGURE 5

A preliminary design of a permanently manned space station NASA has under development for launching in 1995.



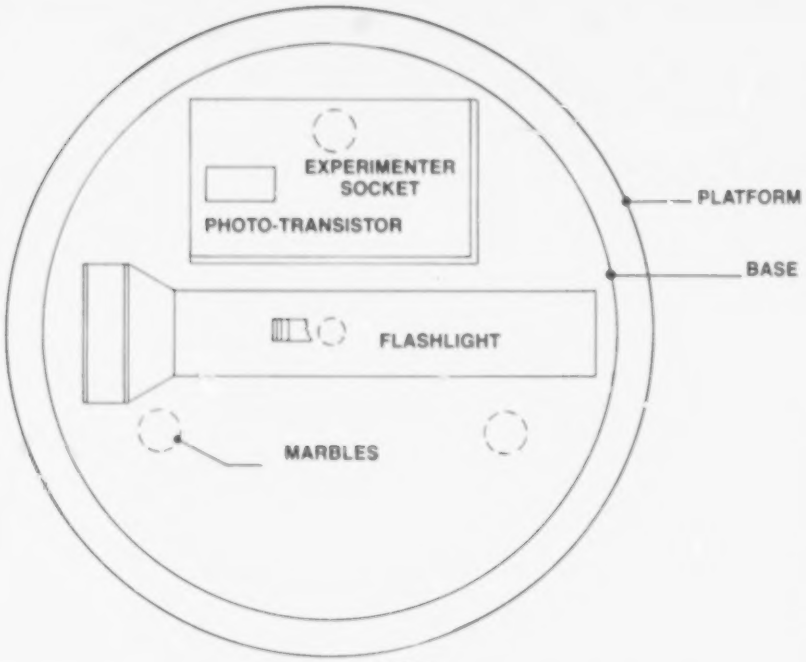


FIGURE 6
Earth Station Parts Layout

Constructional Activity

The concept of a passive satellite may be easily illustrated by the activity that is described in this section. If you will recall a passive satellite may be best described by its function. Generally, a passive satellite "reflects" or relays radio signals from one earth station to another earth station in a different location. Figure 6 illustrates the concept.

The passive satellite does not alter the radio signal that is reflected back to earth. It does not "repeat" by amplification or retransmit the signal. It is basically a relector of radio waves. The constructional process is simple and may be fabricated from parts that are readily available from local electronic suppliers. Parts may be substituted according to what is available in your technology education laboratory.

The drawing, figure 7, that is shown uses a turntable fabricated from ¾" plywood with a simple bearing platform that allows a light source and photocell receiver to rotate. This platform assembly represents the earth and a transmitting station. A mirror is placed some distance from the platform and represents the passive satellite.

Conceptually, a signal is sent to the satellite and reflected back to "earth" by the mirror, "passive satellite," and actuating the photocell receiver assembly. You will quickly note that this is not a synchronous satellite system, as the satellite will only relay the signal (light beam) during certain intervals of rotation. Can you describe or alter the system so it will function as a "geosynchronous" satellite system?

A few tips on construction. The platform consists of an 8" diameter base disk and a 7" platform disk. A ⅜" dowel is used for a center post and three marbles or ball bearings are spaced 120° apart and set in counter-bored holes in the base disk. A small flash light that has a narrow-focused beam is used to simulate a radio signal.

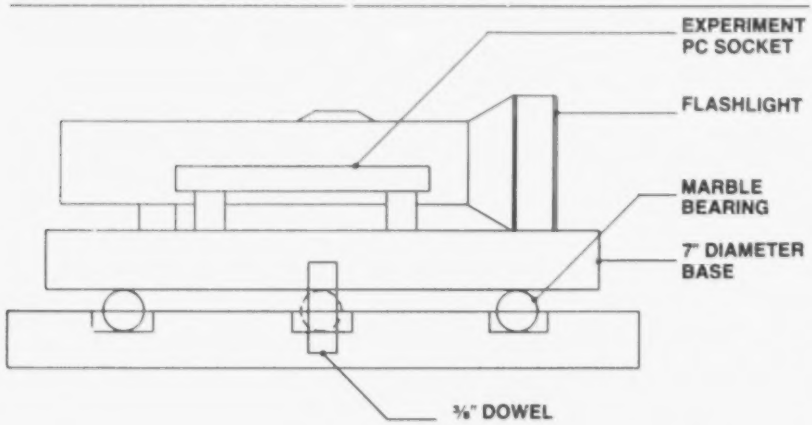


FIGURE 7
Satellite Earth Station Assembly

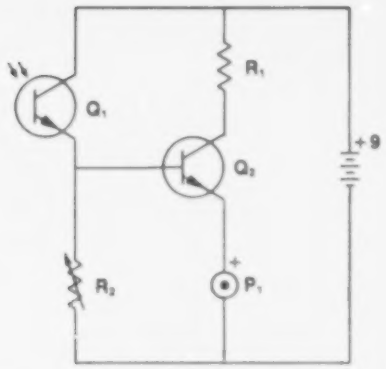


FIGURE 8
Earth Station Satellite Receiver Circuit

The "radio signal" is received by a receiver circuit. This circuit consists of a phototransister and switching circuit to drive a mini-piezo buzzer. When the light beam strikes the phototransistor it will signal the receipt of a "message." To perform the actual simulation a 3" × 3" pocket mirror is used to represent a passive satellite. The process involves the rotation of the "earth station" and as it rotates past the "satellite" mirror, it will reflect the light beam back to the "earth receiving station."

The phototransistor should be mounted in a small diameter tube to minimize ambient light. When the system is set and aligned properly, it will transmit and receive a signal approximately 20 feet. Resistor R_1 limits the current through the 2N2222 transistor and should not be less than 220 ohms. Decreasing the resistance value will increase the sound level output on the piezo buzzer. The potentiometer, R_2, controls the sensitivity of the receiver circuit.

A modular IC breadboard experimenter socket is convenient to assemble the receiver circuit. The breadboard is mounted to the platform disk on spacers beside the flash light. The parts used for this activity should be available from a local Radio Shack Store or most any electronic supplier.

As the above activities and information has shown, satellite communication is a reality in our modern world. Since it is a new technology with a multitude of uses it will have many impacts upon the future.

Parts List for Receiver Circuit

Description	RS Stock Number
9 Volt Battery	23-583
9 Volt Battery Snap	270-325
Modular IC Experimenter Socket	276-175
Q_1 Transistor 2N2222	276-2009
Q_2 Phototransistor	276-145
Piezo Buzzer, PC Mount	273-065
R_1 470 ohm Resistor	271-1317
R_2 1 meg PC Potentiometer	271-229

The Telesat-I (Anik C-1) satellite is deployed from the cargo bay of the Discovery space shuttle. Near the center of the photo is the antenna for Syncom IA (LEASAT) folded in storage position against the U.S. Navy's communication's satellite.

Possible Student Outcomes

- Explain the principles of satellite communication.
- Describe examples of how governments and industries are currently applying communication satellites.
- Analyze issues confronting satellite communication.
- Associate math and science to the study of satellite communication.
- Apply materials and technological knowledge to the construction of a passive satellite communication system.

Student Quiz

1. Explain what a communication satellite is.
2. A satellite that bounces or reflects information back to earth is what type?
3. A satellite that receives, amplifies, and retransmits information back to earth is what type?
4. List and describe the types of orbits that satellites may be placed?
5. Who was the first to propose that satellites be placed in synchronous orbit?
6. What are the disadvantages of placing a communication satellite in a low orbit?
7. What was the first active satellite placed in a low orbit?
8. Explain the phrase "global village."
9. Diagram and explain how broadcasts are made using satellites.
10. List five uses for communication satellites.

Bibliography

Dunlap, Orrin E., Jr. (1962). *Communications in space*. New York: Harper & Row, Publishers.

Gatland, Kenneth. (1981). *Space technology*. New York: Harmony Books.

Man on the Move. (1968). Philadelphia: The Curtis Publishing Company.

Singleton, Loy A. (1983). *Telecommunications in the information age*. Cambridge, MA: Ballinger Publishing Company.

Trocki, Frank R. (1985, March). *Satellite communication: an innovative teacher strategy to teaching technology education*. Paper presented at ITEA/CIEA Joint Conference, San Diego, CA.

11

Nature and Properties of Engineering Materials

Figure 1

Optical fibers made of high purity glass. The nature of these glass waveguides provides superior optical properties enabling them to transmit light, carrying thousands of voice signals over a kilometer without further amplification.

Introduction

This instructional module continues the series on engineering materials technology started with "New Materials" which in the May/June, 1985 issue of *TTT*. The topics of ceramic materials and composite materials will comprise two more modules to follow this one.

The four modules should provide an appropriate introduction to engineering materials especially if *Engineering Materials Technology* (see acknowledgements) is used as a resource since it provides many tables, illustrations, and applications of materials plus numerous references to additional resources.

Also, the *Materials and Processes Technology Instructional Resource Guide* from the Technology Education Service, Commonwealth of Virginia offers a guide to competencies on the subject. Such periodicals as *High Technology, Popular Science* and *Discover* provide information on new developments in engineering materials technology.

Expanding on the concepts developed in the module "New Materials," you will see that a material's nature, which involves its internal structure, dictates the properties of the material. With the examples of the nature and properties of materials from our "family of materials" presented earlier, you are on your way to understanding how materials selection becomes a key factor for an engineering designer who begins product design. Also, knowledge of materials allows you to be a wiser consumer of products and to better understand how to care for products that you own. For those who find this study interesting, many career opportunities await including the study of design/manufacturing technology, materials science and engineering, welding and nondistructive testing technology, and electromechanical technology to name but a few.

Social-Cultural Impacts

Each year numerous new materials enter the family of materials. On the price of a manufactured product, 40% of the cost comes from material costs. In the case of aluminum, to produce this light weight, corrosion resistant, nonferrous metal from bauxite ore, it requires huge amounts of electrical energy: 4% of all metal processing energy. However, through recycling of aluminum cans, foil and other products made of aluminum, we save 95% of that electrical energy. For copper to serve as a conductor in telephone lines, printed circuit boards, and similar applications, it must be 99.9% pure. Such purity takes great amounts of electrical and chemical energy.

The United States already consumes about 100 times the energy of the average underdeveloped nation. This country only comprises about 6% of world's population but consumes about 33% of its energy. New alloys, "superconducting" materials, optical fibers, amophorous metals ("metglass"), lasers and other high tech materials developments aim to reduce energy consumption [Jacobs & Kilduff, 1985, pp. 11–14, 218–223].

Engineering materials technology faces a challenging future with limited resources to meet the demands of an ever increasing world population that always wants new and improved products. We need intelligent citizens who know the importance materials play in our society and can make informed decisions regarding governmental action in 1) managing natural resources, 2) controlling manufacturing processes to reduce dangers of environmental pollution, and 3) insuring the safety of materials in such products as food containers, childrens' toys and furniture, and airplane interiors.

Nature/Structure of Materials

Every aspect of a material results from its internal structure. This nature or essence of a material yields properties of the material. For example, the color of a piece of metal results from the way in which light atoms *(photons)* are absorbed (or not absorbed and reflected) by the atoms within the metal. Certain plastics, such as acrylics and styrene can be formulated so that photons pass through them.

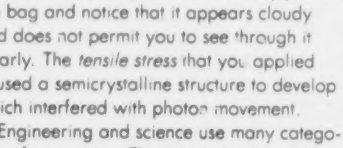
Try this. Take a polyethylene sandwich bag and notice that you can see through it since its amorphous structure allows photons to pass without absorption. Now slowly pull on the bag and notice that it appears cloudy and does not permit you to see through it clearly. The *tensile stress* that you applied caused a semicrystalline structure to develop which interfered with photon movement.

Engineering and science use many categories of properties. These include physical properties, chemical properties, and manufacturing processes properties. Each of these broad categories are further broken into subcategories. Further explanation of properties will come later in this module.

Atomic Bonding

In the "New Materials" module (May/June, 1985) you learned about atomic structure and that the Family of Materials breaks into major groups: metallics, polymerics, ceramics, composites, and other materials. Materials fit into their groups based on their similarities of nature/structure and properties. The manner in which atoms and chains of atoms bond together to form materials gives an internal structure which determines materials' properties.

Covalent bonds make up the primary way polymers and other organics (hydrogen and carbon compounds) bond together; it exists in varying degrees in ceramics. Covalent or *electron-pair bonding* involves the sharing of two or more electrons between atoms. Figure 2 illustrates covalent bonding in a semiconductor made of a ceramic (Si-silicon) and a metal (Al-aluminum). In this case *double* covalent bonds are formed with two electrons shared among the Al and Si, but one electron is missing to form a "hole." If electricity is applied, an electron will fill the hole with an electron thus conducting an electrical current (Jacobs & Kilduff, 1985, pp. 406–407).



Al = Acceptor atom

FIGURE 2

Covalent bonding of silicon with aluminum atom added as a dopant.

Ionic bonds found in inorganic materials such as metals and ceramics involve the transfer of electrons. Figure 3 depicts ionic bonding between sodium (Na) and chlorine (Cl) in which *valence electrons* (outer orbit electrons) in the Na atoms transfers to the Cl atom to form sodium chloride (table salt).

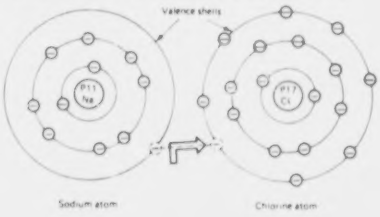


FIGURE 3

Ionic bonding of sodium and chlorine to form molecule of sodium chloride (table salt).

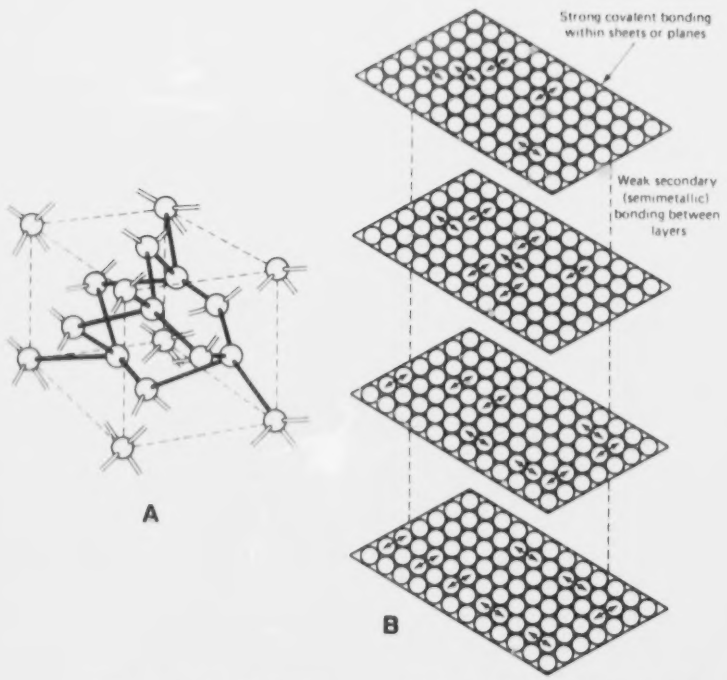
You need to make a study of the Periodic Table of the Elements to fully understand why valence electrons share in covalent bonding and transfer in ionic bonding.

Metallic bonds exist in metals such as iron, aluminum, and copper plus metal *alloys* including steel, brass, and solder. Figure 4 shows these bonds yield a cloud of weakly bonded electrons which can be easily moved when an electrical current or heat is applied to the material. For this reason metals posses good properties of electrical and thermal (heat) *conduction*. In contrast, polymer and ceramic electrons bond tightly to provide good electrical and thermal *insulating* properties.

FIGURE 4

Metallic bonding with ions of metal surrounded by cloud of ions.

Secondary bonding produces bonds between atoms and chains of atoms *(molecules)*. The weaker secondary forces allow atoms and molecules to move about. For example, carbon (C) exists in several forms; it



A) Diamond with strong coivalent bonding among all atoms.

B) Graphite with weaker bonding system.

FIGURE 5

Allotopes of carbon.

is *allotropic* or *polymorphic*. In diamond, our hardest natural material, C exists as an allotrope with a perfect cubic structure whereby each C atom forms strong covalent bonds with four other neighboring C atoms (Figure 5a).

Another carbon allotrope is graphite, a very slippery material used as a lubricant. Graphite also has strong covalent bonds between C atoms but only within layers. Between layers of graphite, C forms weak secondary bonds which allow the layers to slide easily past each other with application of slight force (Figure 5b).

Secondary bonding also develops in the group of plastics known as *thermoplastics*. The secondary bonds (Figure 6a) allow thermoplastic plastics, such as acrylics and nylon, to be heated and shaped over and again because secondary bonds do not hold the polymer chains together as strongly as the covalent bonding of atoms within the chains.

On the other hand, *thermosetting* plastics, such as phenolic, certain polyesters and epoxies, and silicones form covalent bonds *(crosslinks)* between chains as well as within chains (Figure 6b). These plastics cannot be softened and reshaped once the resin cures, and often function at higher service conditions than do thermoplastic plastics.

A Crosslinked linear polymers (e.g., polyesters and diene elastomers)

B Thermoplastic polymer

FIGURE 6

Polymer chain bonding.

Micro and Macrostructure

The atomic bonding just discussed cannot be seen, instead nuclear and materials scientist use devices such as electron beam accelerators, spectroscopes, and X-ray diffractometers to see how the inner atomic particles react to external forces. With aid of electron microscopes and metallurgical microscopes, materials scientist, engineers and technicians can observe the *microstructure* of materials.

The *macrostructure* of materials such as wood grain and laminations in a composite dime (silver alloy laminated to copper) are easily seen with the unaided eye. Microstructure results from atomic bonding as well from the processing technique.

Grains appear in many materials, some are microstructure others macrostructure. Figure 7a shows macroscopic wood grain (end grain, quartersawn grain and plain sawn grain) of a cedar board. The grain direction dictates strength of the wood. Figure 7b provides a view from a metallurgical microscope of medium carbon steel magnified 200 times (200X) to reveal iron (Fe) and iron and carbon grains. Figure 7c shows the amorphous structure of polyethylene as taken with an electron microscope capable of 10,000 X and more magnification.

In metal, grains begin as *crystals*. First molten metal cools to a point that nuclei form at various spots (Figure 8a), the nuclei grow into crystals called dendrites (8b), dendrites grow until they meet other dendrites to form the *polycrystalline* or multiple grain metal as it cools to a solid (8c). Many factors affect the properties of the final solid metal.

Alloying begins the process of determining properties as exact quantities of elements are

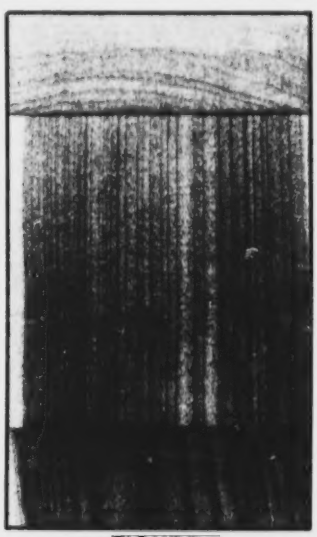
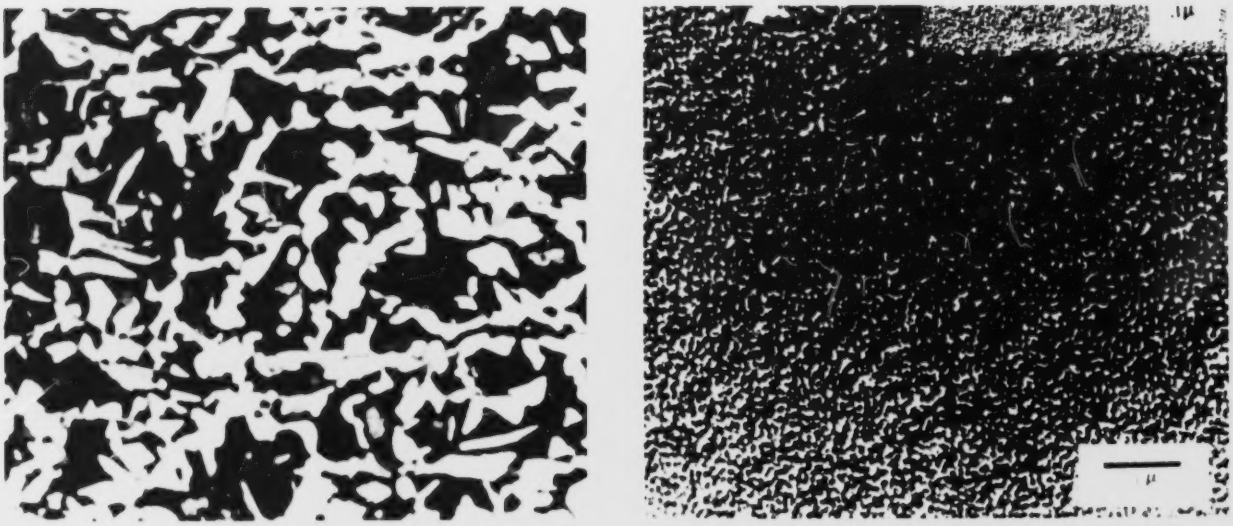


FIGURE 7

Macrostructure of (from top) cedar wood end grain, quarter sawn grain, and plainsawn grain.



Microstructure of a) grains of steels; and b) amorphous polyethylene.

combined. This all important combining process is crucial to production of solid state materials of desired properties just as the recipe is crucial in making a good tasting pizza. For steel to become hard enough to be a razor, the right amount of carbon must be added. With plastic and other manmade polymers the right elements are added during the *synthesis* stage. With ceramics basic properties are developed for glass when all ingredients are mixed and melted, but with concrete and most other ceramics, ingredients are dissolved in water to form a slurry and combine through curing by *hydration*.

Casehardening is a technique of adding elements (carbon) to the surface of steel to add surface hardness even though the material is in the solid state. Ion implantation is a new technique that adds elements to solids. Colorants, flame retardants and rubberizing compounds (plasticizers) are typical agents added to liquid or solid plastic before final processing to change properties of the original resin.

Cooling rate then plays the next role. The sketch in Figure 9 indicates that a slow cooling rate was used on this steel to allow almost pure iron (Fe) to form along with iron carbide (Fe_3C) in a homogeneous structure. *Homogeneous* structure is the same in all directions and the properties are the same in all directions or *isotropic*.

Polyethylne, as with most plastics, when cooled at a slow rate takes on an amorphous structure rather than a crystalline pattern (Figure 7c). Glass is different than most other ceramics with its normally amorphous structure that develops from slow cooling into the solid state.

FIGURE 8
Stages in metal solidification.

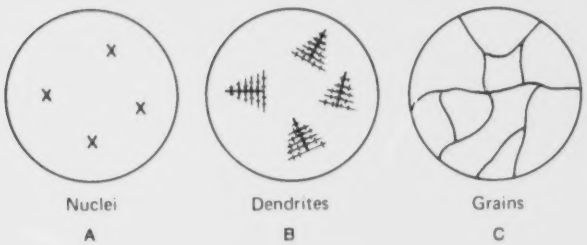
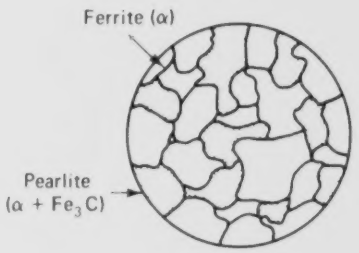


FIGURE 9
Steel microstructure.



15

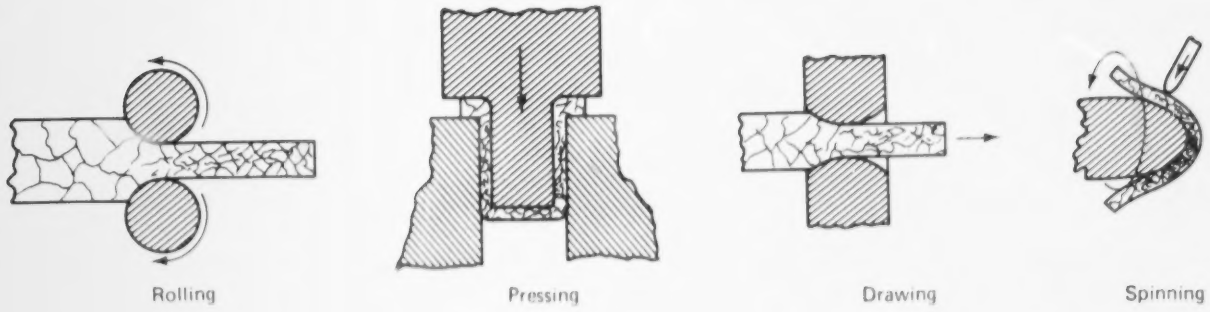


FIGURE 10

Directional properties developed through both hot and cold forming of solid metals

Changing Structure and Properties

Figure 10 shows four common means of changing the crystalline or grain structure of metals while they are still in the soft, hot condition known as the *plastic* state. Notice that the direction of the forming determines which way the metal grain runs. Once formed the metal becomes *anisotropic*: properties are varied by direction.

We accomplish anisotropic structure in plastics by pulling or pushing them through dies to change their amorphous structure to semicrystalline (Figure 11) just as you did by pulling the polyethylene bag.

Try this: Use a portion of the bag which has not been stressed. Pull with light pressure in the direction of the bag opening then pull another portion 90 degrees to the opening. Because the bag was made by being forced through a die it should be stronger (semicrystalline) in one direction.

Thermal Processing (heating and cooling) is another means of changing properties in solid materials. With proper ingredients alloyed, compounded, implanted or otherwise placed in a solid, the material might be heated to achieve the desired property.

The razor that had carbon alloyed for hardness is heated to a point that small carbon atoms fit between iron atoms. The razor is then rapidly quenched in water or oil to trap the carbon in place and make a hard, brittle steel. Chromium was also alloyed into the razor to give good corrosion resistant properties.

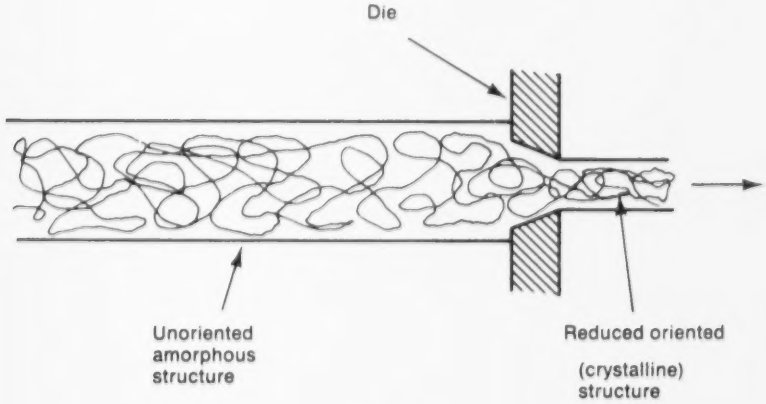
In the module on ceramics to follow later, you will learn how heat treatment of glass can dramatically alter the properties of this material which is normally brittle with limited processability.

This module only touched on properties of materials as they related to structure. Most of these properties focused on the end product. Processing properties are also important. Ease of bending or forming involve the properties of *plasticity, malleability,* and *ductility.* These properties are varied in metal during processing.

For example, to make a cold chisel or center punch of steel, we machine the steel in a soft *(annealed)* state to avoid dulling our cutting tools. Then we heat the cutting or punching tip and quench it in water to give a very hard tip. The opposite end is in a tempered state with a degree of softness so a hammer gradually mushrooms towards that end instead of shattering as it would if the whole tool was hard and brittle.

FIGURE 11

Polymer forming results in crystalline structure and anisotropy.



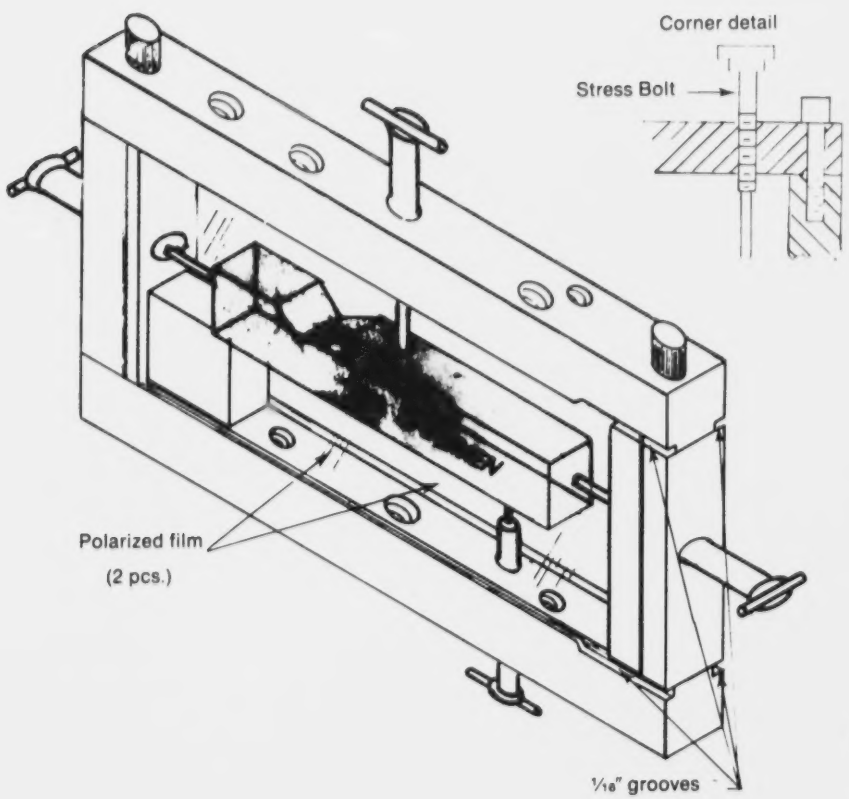
Construction Activity

In this instructional module, we used the term stress a number of times when referring to properties of engineering materials. Most often used in conjunction with mechanical properties, stress cannot be seen. You can observe the results of stress as with electrical current. When turning on a light switch one does not see electrons flow, but sees the result of the flow as the light glows due to heat generated by electrical resistance of the light bulb filament.

The result of mechanical stress shows when a force is applied to a material and it bends, twists, shears, stretches or collapses. Stress concentrations develop at weak spots in a material, especially where sharp cuts or tears are present. For this reason good design includes fillets and rounds that interrupt sharp intersections of corners.

It is possible to observe *stress* which is the effect of force in a material with a polarized stress demonstrator. Construct a frame similar to the one shown above. The frame can be made of 5/8" square aluminum bar stock and bolted together after 1/16" grooves are milled as shown. The polarized film is inserted in grooves on both sides of the frame. Specimens of various shapes cut from 1/2" polarized plastic stock is mounted in the frame. Screws or bolts are used to apply stress. Notches and holes in the specimen will show stress concentrations as will points in which the specimen is placed in compression, tension, or torsion. Light is polarized through film and dramatically shows stress concentrations in various colors. The frame can be placed on an overhead projector for a group demonstration. The polarized plastic film and polarized plastic bar stock can be ordered from Photolastic Co., 67 Lincoln Highway, Malvern, PA 19355.

FIGURE 12
Polarized Stress Demonstrator



Math/ Science/ Technology Interface

What is Specific Gravity?

Objective: To define specific gravity and to show how it varies among species.

Material: Wood specimens 1" × 1" × 10" of white pine, southern pine, oak, and aspen. A 500 cc. graduated cylinder, drying oven, balance, and ruler.

Method: The first method used here to determine specific gravity is called the flotation method, because the value is found from the amount of specimen below the surface when it is floating in a liquid.

First, place the wood samples in an oven

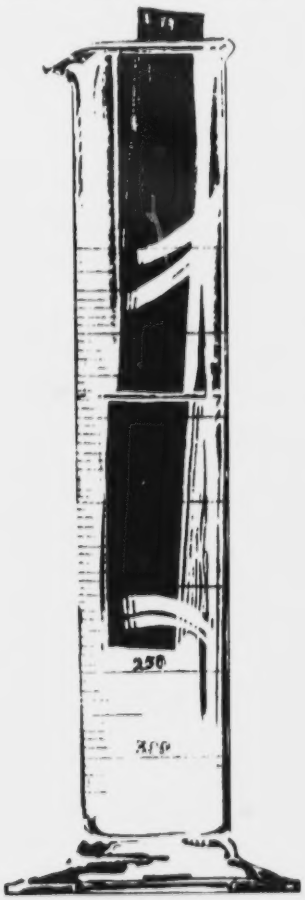


FIGURE 13
A tall glass cylinder is necessary for the specific gravity test so that the block will float almost upright giving a water mark at approximately a right angle to the length of the specimen.

at 105°C. overnight to remove excess moisture. Remove each specimen from the oven, weigh it, replace in the oven for about two hours and reweigh. Repeat until each specimen reaches a constant weight indicating that as moisture as possible been removed. The sample then is ready to be placed in the cylinder.

A graduated cylinder is suggested, but any vessel in which the sample is force to float upright can be used. The cylinder should contain enough water to float a specimen with its top above the cylinder. Gently lower the specimen into the water, taking care not to allow it to sink too deeply. When it has reached its float level, withdraw the specimen from the water and measure the length of the sample which was under water.

Observation: Specific gravity of an object is obtain by dividing the weight of the object by the weight of an equal volume of liquid.

$$\text{Specific gravity} = \frac{\text{weight of object}}{\text{weight of equal volume of water}}$$

Any liquid may be used, but water is the most common.

The concept of specific gravity comes from Archimedes' principle which showed that an object floating in water was being held up by a force equal to the weight of water displaced. If a sample sank to where the surface of the water coincided with the top of the sample, the specific gravity would be 1.0. Thus for the sample by our formula:

$$\text{Specific gravity} = \frac{10}{10} = 1.0$$

Let us assume that the specimen sinks only four inches into the water, that is, the weight of the specimen is supported by the force of 1 by 1 by 4 cubic feet of water. Thus, by the formula:

$$\text{Specific gravity} = \frac{4.0}{10.0} = 0.4$$

This is the specific gravity of the entire wood, this is, the cell walls and the spaces in the cells. This value varies for different woods because some woods have more air space or more cell wall materials than others.

The weight, or density, of the cell wall is the same for all woods, about 1.5. While this value is constant, the amount of cell wall material in a definite volume of wood varies considerably.

Application: Because specific gravity is a measure of the amount of cell wall material in wood, it is a useful indicator of strength properties and of suitability for various uses. Heavy woods, such as Douglas fir, southern pine or oak as used for heavy construction, while lighter ones, white pine or aspen for example, as desirable where load bearing is not the prime consideration.

Supplementary Activity

To learn about the nature and properties of materials in common objects try this activity.

1. Locate some defective object around the house such as the light receptacle shown below, old toys, hair dryers, parts off of automobiles or any other object that has multiple materials in it.

2. Disassemble the part and mount it on posterboard using adhesives, thread, or wire, then place a number next to each piece.

3. Beneath the disassembled object set up the following columns:

Piece No.	Name	Material	Property

4. To determine the material you will need to do some research in books such as the reference for this module. For the properties column, use the same references and determine what favorable properties probably caused the materials selection; e.g. item 3 below is part of the socket base made of aluminum with favorable properties of good electrical conduction, corrosion resistance, and easy of forming. Item 6 is a cardboard insulator with good electrical insulating properties and low cost.

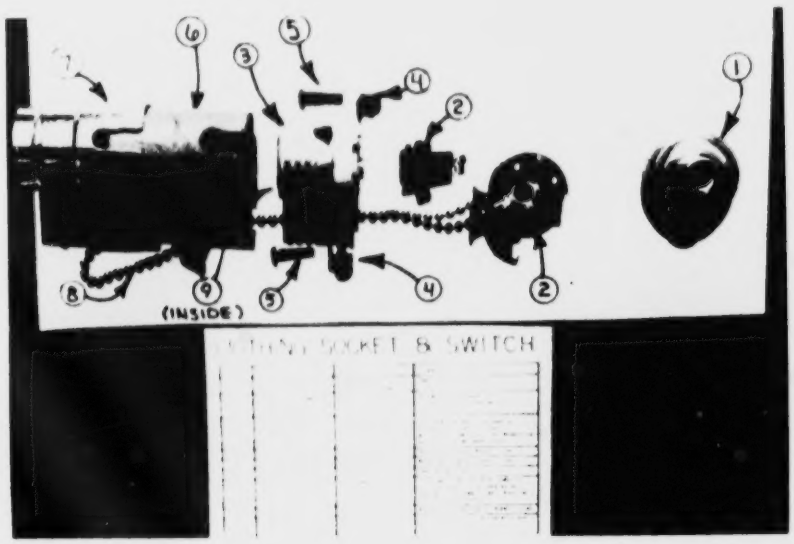


FIGURE 14
An example of the supplementary activity board in examining a light bulb socket.

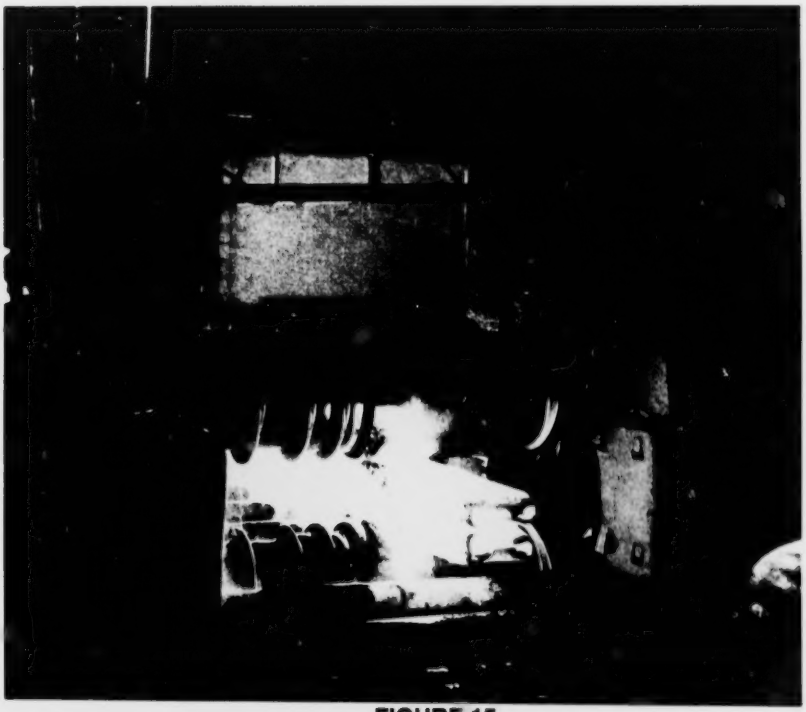


FIGURE 15

Blooming mill shapes solid steel in its "plastic" state. This not only yields desired shape but also improves mechanical (directional) properties.

Student Quiz

1. Make a sketch to represent each of the following types of atomic bonding; use appropriate labels:
a. covalent (see Fig. 2) b. ionic (see Fig. 3)
c. metallic (see Fig. 4).

2. Name a group from our Family of Materials that has the following type of primary bonds:
a. ionic *(ceramics or metallics)* b. covalent *(polymers or ceramics)*

3. Name two favorable properties that result from metallic bonding.
a. *thermal conductivity*
b. *electrical conductivity*

4. What is the nature of bonding that causes (a) thermoplastic plastics to allow continuing resoftening but (b) prevents thermosetting plastics from being resoftened once the resin cures.
a. *(weak secondary bonds hold thermoplastics' chains together)*
b. *strong covalent bonds link together thermosets' chains)*

5–8 Underline whether the statement is true or false:

5. True False Macrostructure refers to very small structure that requires a macroscope to see.
6. True False Scientist can see atoms and stress with metallurgical microscopes.
7. True False Once in the solid state it is possible to change properties of the solid.
8. True False Since diamond is the hardest natural material and made of carbon, other carbon based materials have hardness equal to diamond.

9. Which term involves adding elements to change properties in metals?
a. hydration b. synthesis c. allotrope
d. alloying

10. Which term refers to properties equal in all directions?
a. anisotropic b. casehardened c. isotropic
d. grain

Possible Student Outcomes

- Sketch and apply appropriate labels for the primary bonds found in the major groups of our Family of Materials.
- Recall the nature of secondary bonds and their affect on thermoplastic plastics and why thermosetting plastics bonding gives different properties.
- Explain the difference in microscopic and macroscopic structure and give examples of each type of structure.
- Explain how properties develop in materials during the formulation of the material and after they are in the solid state.
- Describe the events that occur as a metal cools into a solid and how the events and structure differ in most glasses and plastics.
- Define the following terms:

grain	processing
crystal	properties stress
isotropic	photons
anisotropic	alloying
homogeneous	hydration
casehardening	allotrope polymorphic

- Analyze personal interest in the study of engineering materials technology to determine if you wish to pursue further study in one of numerous possible vocational and/or college programs.

Reference

Jacobs, James A. & Kilduff, Thomas F. (1985). *Engineering Materials Technology*. Englewood Cliffs, NJ. Prentice-Hall, Inc.

Acknowledgements

Figure 1 supplied by Corning Glass Works.

Figure 2–6, & 8–10 James A. Jacobs & Thomas F. Kilduff (1985). *Engineering Materials Technology*. Reprinted by permission of Prentice-Hall Inc. Englewoods Cliff, NJ.

Figure 7a supplied by U.S. Forest Products Laboratory.

Figure 7b supplied by American Iron and Steel Institute

Figure 7c supplied by Dr. Philip H. Geil, University of Illinois.

Figure 15 supplied by Bethlehem Steel Corporation.

Specific gravity experiment taken from *Classroom Demonstration of Wood Properties*, U.S. Dept. of Agriculture, Forest Products Laboratory. May be ordered from Superintendent of Documents, U.S. Printing Office, Washington, DC 204C2—60 cents.

Careers in Technology

Even the most casual observer recognizes that technology continues to accelerate at an ever-increasing rate as it spews out one innovation after another. But how many stop to consider how this advancing technology promises to affect their careers? Requirements for many of today's jobs have already changed; however, most people do not realize it until they begin considering a job change. When they look for a new position under their present job title, they may be shocked to learn that the new position requires knowledge and skills that they do not possess.

In the near future, many jobs will be eliminated and even more will crop up to replace the obsolete ones. In the distant future, but still within the working life of younger employees, making predictions about the job scene will become an impractical task.

This Resources in Technology will allow you to examine some of the forces that create change in occupations, see the types of newly-developing and much-needed careers fostered by the driving forces, and learn how to pursue education and training in preparation for entering a career that appeals to you. Limited space permits us to develop only some basic, but key, concepts that will make you a wiser evaluator of careers. These concepts can help equip you to deal with the lifelong task of learning about occupations and to keep current with occupational changes.

Social–Cultural Impacts

The United States has lost its ability to meet global competition as Japan, Germany, and other nations have surpassed the U.S. in quality and low or moderately priced products, ranging from televisions to automobiles to industrial equipment, such as machine tools and robots. Japan's productivity is five times that of the U.S. These factors contribute to a large trade imbalance between nations, with the U.S. sending more money abroad than it is receiving. With this imbalance of trade, the U.S. may lose many jobs for its citizens. To regain its competitiveness, U.S. industry must increse productivity.

The movement toward improved productivity and better quality products involves automation, which means many manual jobs disappear. That is the bad news. The good news is that automation creates a need for more technologists. The term *technologist* has several meanings. Here it means engineers, technicians, and scientists—those people with technical knowledge and skills. John Young, the president of Hewlett-Packard and chairman of the President's Commission on Industrial Competitiveness, stresses the need to consider education as a lifelong process and says we must prepare to provide continued retraining for adults (Young, 1985).

Projections of future jobs reveal a serious mismatch of requirements for the new jobs and preparation of those seeking the positions. People displaced by new technology may seem logical candidates to fill the new jobs created by that same technology; however, they often lack the prerequisite knowledge, skill, and attitude to qualify for retraining. In an article on the growing mismatch between jobs and job seekers, Drucker (1985) points to the need for people to possess certain attributes for them to be retrainable. These people need "technological literacy," a fair theoretical base in basic sciences, and an attitude that enables them to adjust to change.

The editor of *High Technology* informs us that our current skilled and semiskilled workers will not only be displaced from their jobs by automation; but even worse, a large segment of the younger generation will lack preparation to deal with demands of tomorrow's high-tech world, thus preventing them from filling the new positions. This prediction results from the fact that many school districts do not provide the proper education to deal with the kind of technically oriented occupations for the future. A growing population of unemployable citizens may develop in central cities, rural areas, and the "rust belt" (steel- and auto-producing states), while high paying and frequently changing jobs develop in technology-based communities (Haavind, 1985).

Evidence of the need for technically competent workers abounds in employment advertisements, such as those seen in *Commline: The Journal of Computerized Manufacturing*. One issue listed current base salaries for jobs that ranged from $50,000 for NC (numerical control) and CNC (computer numerical control) managers, to $44,300 for CAD (computer-aided design)/CAM (computer-aided manufacturer) engineers, to $34,000 for a long list of technicians in NC, CNC, and CAD/CAM positions ("NC/CAD/CAM," 1985). Predictions through 1995 by the U.S. Department of Labor's Bureau of Labor Statistics show a bright future for people educated in engineering, math, and science. In the comparisons of percentages of increases over those employed in 1982, the following samples indicate the typical gains anticipated by 1995: engineers in all fields–49%, industrial engineers–42%, metallurgical engineers–47%, electrical engineers–65%, mechanical engineers–52%, electrical/electronic technicians–61%, drafters–5%, computer programmers–77%, computer technicians–97%, mathematicians–26%, chemists–22%, lawyers–34%, physicians–34%, computer-system analysts–85%, agriculture scientists–19%, and biological scientist–36% (*NY Times*, 1985).

The above statistics have many implications for the occupational outlook for countless job categories. Obviously, we cannot deal with all of them here, rather we will focus on the engineering team because the team members must play a role in increasing the world trade competitiveness of any nation. A nation should enjoy a good standard of living with a good balance of trade.

The Engineering Team

We begin our study with the engineering team because most work done in engineering involves a team effort. The team members include scientists, engineers, technicians, and crafts people. Sometimes the term *technologist* is used in labeling a specific team member; however, the term has several meanings, with many using it to designate any member of the technical or engineering team. Our discussion will avoid the technologist.

The engineering team (also known as the **technological** or **technical team**) centers much of its activity around **problem solving.** This means team members constantly look for solutions in such areas as malfunctions of equipment, new and improved techniques to processes, chemicals, better manufacturing techniques, or clearer and more precise methods to communicate technical ideas. When learning the descriptions of team members, keep in mind that all members should be good at critical thinking. They must possess the ability and willingness to revise judgments in light of newly presented principles or findings. They need to view problems objectively and without interjection of personal biases and must employ creativity.

FIGURE 1
The Engineering Team: Relationship Between Positions, Education, and Nature of Work

Position on Team	Craftsperson ↓	Technician ↓	Engineer ↓	Scientist ↓
Education and Training	← Emphasis on mechanical skills ←			
	→ Emphasis on abstractions →			
Nature of Work	← Production, Maintenance, Operation ←			
	→ Supervise, Design, Research →			

Direction of arrows indicate increased emphasis

Scientist

The scientist comes first in this discussion because much of the time, this kind of technical person originates the basic ideas upon which other members of the team build. As the most theoretical member of the team, scientists develop **hypotheses,** from which come **theories** and **laws** of science. Their activity requires much investigation of the phenomenons of the universe. Many years of experimentation may go into an effort to explain matters that seem minor. But in science, explanations of the smallest details help with the large puzzles of the universe. For example, much effort in science today focuses on determining the nature of the nucleus of atoms. Scientists want to discover all the particles in the atom and determine how they help to hold matter together. This study goes back to the beginning of science and has yet to be completed.

These theoretical scientists may have little concern with the practical application of their discovery and leave that to other members of the technical team. Some scientists, who may be labeled **applied** scientists, do engage in practical problems. For example, materials scientists, polymer chemists, and metallurgists use theories and laws of science in their research on new materials for engineering. Today, considerable research goes into materials that will make lighter, longer lasting batteries to replace the lead acid batteries currently used in automobiles.

Scientists require a strong academic background and usually study for seven to nine years in colleges to earn a doctorate degree. Like most of the members of the engineering team, their education does not stop with the doctorate; they must continue to study the remainder of their working life.

The diagram in Figure 1 shows a comparison of the members of the engineering team. With scientists, the nature of their education and the nature of their work places emphasis on mathematics and sciences, such as physics and chemistry.

A team of scientists involved in the development of a process for making semiconductor crystals.

A CAD station allows a design engineers to speed the design process many times over manual drafting.

Engineer

Engineers use the basic principles developed by scientists for problem-solving efforts that involve systems, products, and procedures that incorporate **standards** and **specifications.** Practical applications of scientific discoveries drive the engineer. They strive for improvement and must always wonder if a "better way" might be found for a present process, product, or procedure.

Many areas of specialization exist in the field of engineering. Figure 2 lists but a few. These fields cover the areas in which all members of the engineering team may find employment. Later you shall see that much specialization also exists within the engineering fields of specialization.

The most direct route to becoming an engineer is to complete a bachelor's of science degree or master's of science degree in engineering from a college or university accredited by ABET (Accreditation Board of Engineering and Technology). These engineering degree programs require extensive study and use of mathematics and science. One must have an aptitude and strong interest in math and science to succeed in traditional engineering programs.

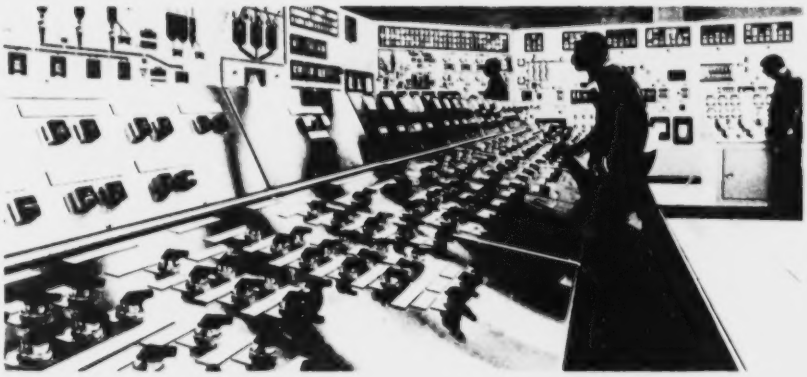
Other less direct routes exist for entry

FIGURE 2
Specialized Fields of Education

Aeronautics
Aerospace
Agricultural
Architectural
Bioengineering
Ceramic
Civil
Electrical
Industrial
Manufacturing Systems
Marine
Materials
Mechanical
Metallurgical
Mining & geological
Naval
Nuclear
Petrochemical
Semiconductor
Structural

into positions entitled **engineer.** Many people employed in private industry with this title did not graduate from an ABET-accredited engineering program. This group of engineers may have served apprenticeships, gained much work experience, and supplemented their education through company-sponsored programs. The combination of work experience, and education make them valuable employees. However, these people may find that their experience would not guarantee them a position of engineer if they sought work with another employer.

Still another route exists for moving to the rank of engineer. This route involves study in **industrial** and **engineering technology** programs. These relatively new programs may be ABET accredited or accredited by NAIT (National Association of Industrial Technology). The degrees are known as bachelor's of technology, bachelor's of engineering technology, or bachelor's of science in technology. Normally, these programs do not require as many math and science courses, even though they do involve application of both. More emphasis goes into laboratory work, skill development, and applied engineering. These people prove themselves as field engineers in CAD/CAM and NC work or other areas where equipment and manipulative skills are needed. Many first complete an AAS (associate of applied science degree) at a community or junior college and then go on to finish their bachelor's degree in a four year college or university. A **2 plus 2 program** is the popular name for this route to a bachelor's degree.



Technicians operating a modern steel mill.

Technician

Technicians employ skill and knowledge in all phases of engineering depicted in Figure 2. As seen by the emphasis in Figure 1, technicians rely on familiarity with tools, equipment, and apparatus. They often undergo specialized education and training that emphasizes manipulative skills, such as with mechanical or electrical testing equipment. They may work on production lines as troubleshooters to keep the equipment running. In construction, they use such instruments as transits or levels. They maintain sophisticated equipment, such as computers, NC tools, aircraft, and spacecraft. Some operate CAD systems in design/drafting jobs.

Two groups of technicians related to the technological team are **engineering technicians** and **scientific technicians.** They gain entry into these positions through various routes. Apprenticeship programs once were a common preparation, and although apprenticeships are still important in some specializations, the AAS degree seems to have become the more popular route. As previously discussed, community and junior colleges offer these programs where students gain both skill and fundamental knowledge of math and science and in-depth knowledge in a technical specialty. By a combination of job experience and further education, such as 2-plus-2 programs, technicians often assume increasing responsibility. Some may supervise other technicians, clerks, and crafts people, while others become more adept in their technical specialty.

Crafts Person

Skill marks the craftsmen group as we see in Figure 1. They use hand tools, operate machines (e.g., lathes, forging presses, or welders), and may service and maintain equipment. Crafts people should have a great pride in quality work and derive satisfaction from seeing materials transformed from their raw state to finished products. Education for the crafts usually involves completion of a high school vocational program. Or, some students may finish industrial arts/technology education courses. Certification in a craft often follows an apprenticeship after high school.

The onslaught of technology and automation means the need for many crafts people will diminish, while more technicians and engineers must fill the work force. This also applies to semiskilled and labor jobs. No one could wisely predict that laborers and crafts people may eventually be completely eliminated by automation and robots. In fact, certain service jobs (e.g., janitorial work and food and health service) should increase. People will always yearn for handcrafted products, but the price may be beyond most

This welder represents the many skilled craftspeople employed in the construction industry.

The Team Approach

In most engineering activities, you will see the team approach in operation. Often, it is hard to distinguish the team members as they go about the task on problem solving. A recent visit to a plastic manufacturer showed this to be true. In the development lab, the chemist and chemical technicians had developed a new processes for producing polystyrene plastic. The process was an experiment involving glass, rubber, and metal laboratory apparatus. To verify that the processes was feasible, a small pilot plant was being constructed.

At the beginning of the visit, the team of scientists, engineers, technicians, and mechanics was busy working on the pilot plant. The grease and soot revealed all had pitched in on the job. Without introductions, it would have been impossible to determine the members' positions on the team. Once the pilot proved successful, the new process was scaled up for high-volume manufacture of polystyrene in a full-sized plant.

Figure 3 lists a very small sampling of job titles within the various levels of the engineering team. Consult other sources, such as the *Dictionary of Occupational Titles* and *Occupational Outlook Handbook*, for more titles and descriptions of jobs in engineering. Note the responsibilities and relationships for each team member described.

FIGURE 3
Sample Jobs in Engineering Field

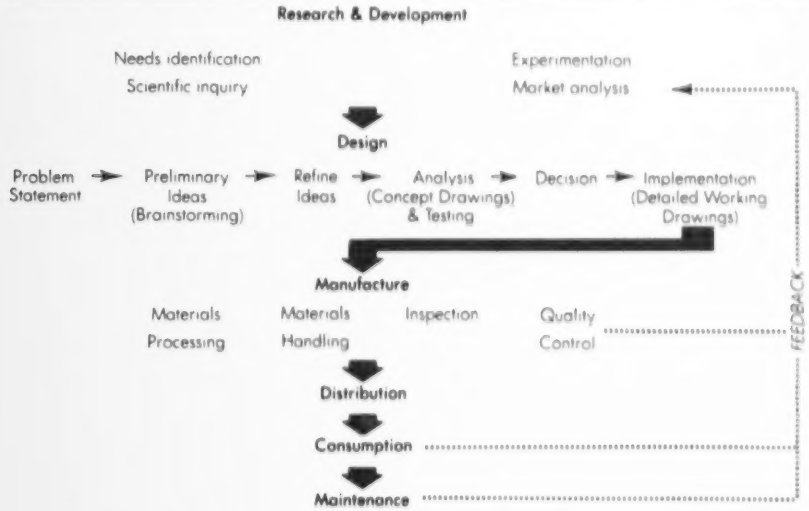
Scientist	Engineer	Technician	Crafts Person
Geologist	Aeronautical engineer	CAD designer	Automotive mechanic
Geophysicist	Civil engineer	Computer programmer	Carpenter
Nuclear physicist	Customer engineer	Electronic troubleshooter	Diesel mechanic
Nuclear physicist	Design engineer	Engineering repair technician	Drafter
Petrochemist	Electrical engineer	Estimator	Heating & A/C Mechanic
Polymer chemist	Field engineer	Mechanical technician	Machinist
Solid-state physicist	Manufacturing engineer	NC programmer	Mason
	Production manager	Robotic technician	Pipe fitter
	Quality engineer	Solar technician	Welder
	Surveyor	Wind tunnel technician	
	Welding engineer		

Predictions of changes in manufacturing show a closer team structure. **Quality circle** techniques place more responsibility on all members of the team and put greater control in the hands of crafts people and technicians. Some see fewer managers needed as factories eliminate foremen and time clocks as they place production workers on straight salaries. Such an approach is designed to increase employee sensitivity to the competitive pressure on the company from other companies and from foreign trade. It should also improve communications among various levels on the engineering team and among the functions of the team (e.g., development, design, manufacturing, quality control, and maintenance) (Brody, 1985).

Engineering Functions

Figure 4 serves as a means to understand the functions of engineering. Beginning at the top, research produces the seeds of ideas which go through further growth in the development stage. Once ideas have germinated in "R&D," they undergo detailed design: a lengthy process which requires consideration of the smallest aspects of the process or system under consideration. CAD holds promise as a means of speeding up the design process.

FIGURE 4
Engineering Functions

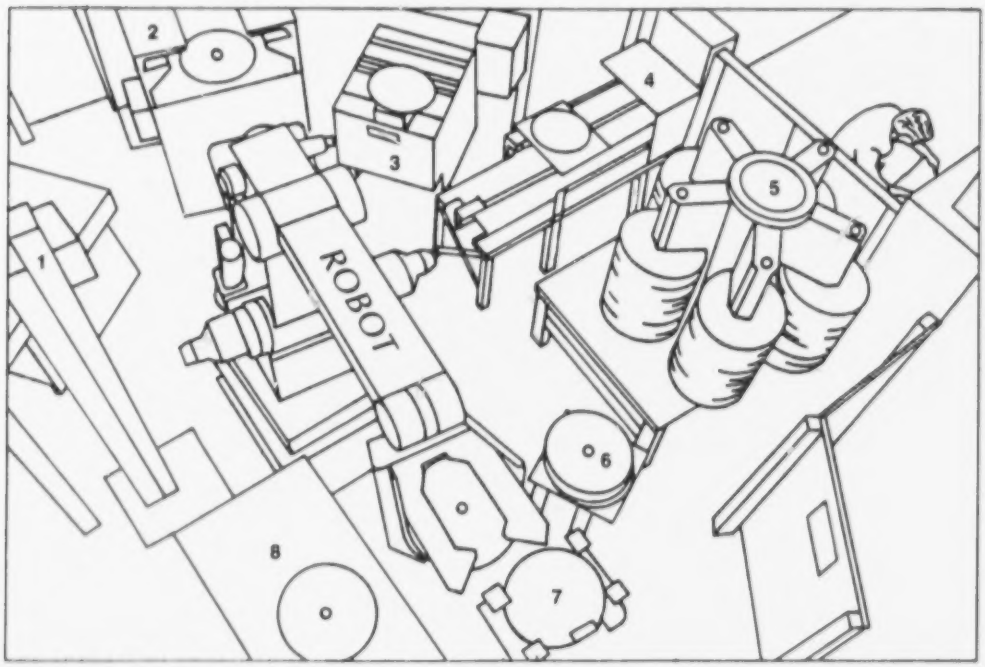


Guided by the completed design and with working drawings, the production team begins to manufacture the product or system. CAM provides a means to automate manufacturing. With CAD systems, the computer-generated data is capable of directly controlling NC machine tools, robots, and automated materials handling equipment. Note the feedback indicated by broken arrows.

"Feedback" refers to verbal information from one team member to another or electronic information sent from machines to humans or machines to machines. This information allows people in any of the functions, from research down, to learn of problems with their ideas so that they may make modifications to solve the problems. For example, once production begins to manufacture a part, they may see that a certain material does not hold up to the bending done on presses. With this feedback data, a new material may be substituted, or perhaps the thickness might be changed and the bending equipment modified.

Figure 5 depicts an automated process, which is one of many steps in manufacturing semiconductor modules. Such modules act as memory and logic devices in computers. The robot in the center of this diagram has elimi-

FIGURE 5
Automated Sintering Furnace Process



1. View machine (measures tiles)
2. Scraper
3. Tile washer
4. Shuttles (Link between system and operator)
5. Index table (tile storage)
6. Reject table
7. Breaker (breaks down, unloads tiles)
8. Hydraulic lift table (Picks tile off table)

nated a number of steps formerly requiring human handling of containers of multilayered ceramic (MLC) modules as they are sintered in a high temperature furnace (1560° C).

Sintering turns soft "greenware" ceramic into hard ceramic. The robot retrieves tiles from storage (station #5), moves them to #2 for both sides to be scraped (bushed and vacuumed), and moves to #3 for washing and hot-air drying. Next, at station #1, an optical measuring machine checks tiles for flatness. Faulty tiles are placed on #6. Good tiles are moved to the shuttle (#4) which transports them to the human operator who assembles the tile containers with MLCs in them. The operator returns the assembly to shuttle where the robot moves them onto a stack at #8. The assembled tile container is now ready for the sintering furnace. Station #7 allows the robot to separate tiles that may be stuck together from sintering (*The Circuit*, 1984).

Robotics provide the engineering team with new machinery for many functions in engineering. Hard automated devices require considerable time, money, and effort to set up and change over for new processes. On the other hand, robots can be reprogrammed with a minimum of time and effort. An engineer or technician might develop several computer programs for the robot. With this ceramic handling processes, the robot could have different programs allowing it to handle different parts.

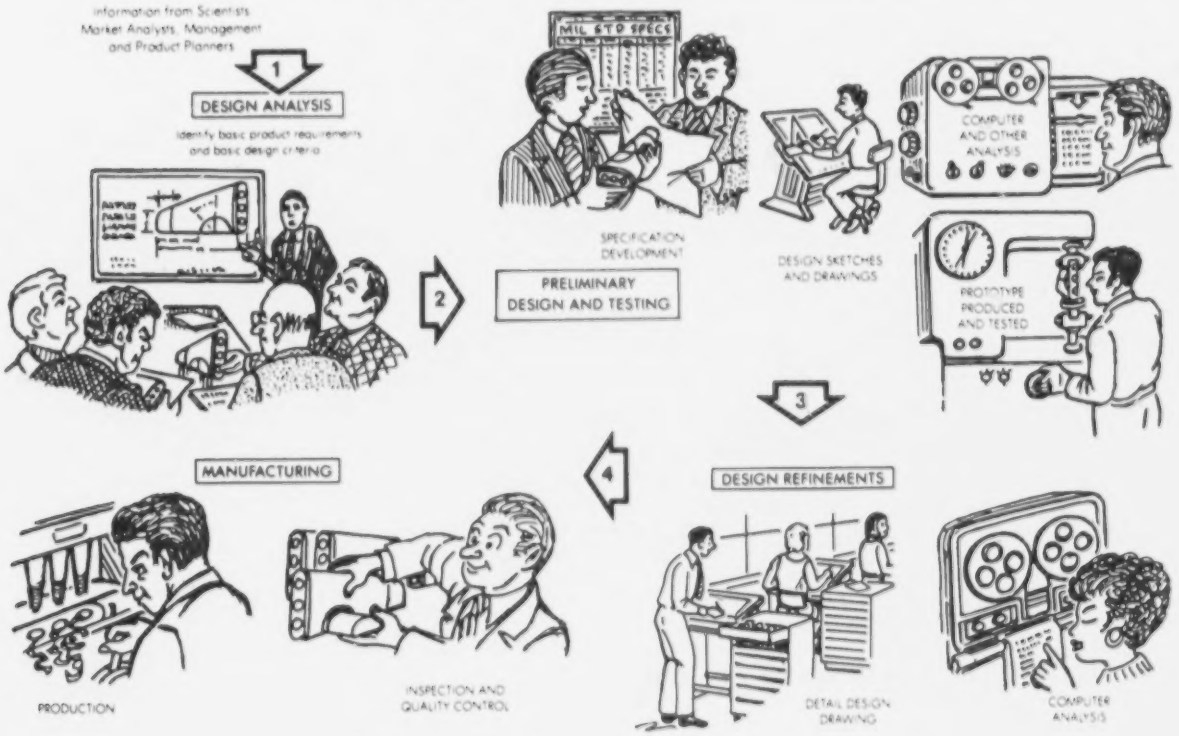
Figure 6 shows the engineering team functioning through various operations to amplify Figure 2. Notes that from preliminary design and testing, a prototype device is produced and tested. This prototype serves to avoid major problems with full-scale production. Just as the pilot chemical plant was first made to produce polystyrene plastic, a small-scale pilot plant may be used to make prototype parts to prevent major problems in full-scale production.

Referring back to Figure 4, we note that engineering functions do not cease once products are manufactured. They become involved in the distribution of products by many means. Distribution can involve ground travel (rails or roads), water, air, and even pipeline. Members become involved in consumption as they work as customer/sales engineers, technical writers, mechanics, and technicians to install products and systems.

Finally, going back to Figure 4, we see the need for the engineering team in maintenance. The service area of engineering has grown as do-it-yourself maintenance becomes difficult as many electromechanical products are very sophisticated. The job outlook for service technicians looks good.

Both consumption and maintenance stages provide feedback to earlier functions of engineering. The feedback feature reinforces our earlier comment that engineering should always be alert to a better means for problem solving.

FIGURE 6
The Engineering Team in Product Research, Development, and Manufacture



Research Activity

Now that you have an introduction to the engineering team, the next step involves pursuing information on a position or positions which interest you. This research activity is designed to accomplish two goals: (a) to find out more about an occupation that you find appealing, and (b) to develop a methodology for gaining career information that will serve you for a lifetime.

The first step in developing information about careers of interest has already been taken when you read this unit of instruction. Also, you have observed people at work, made judgments about the kind of activity that you saw, and learned about conditions of employment. For instance, television carries many detective programs that show a great deal of excitement and romance. If you spend several days with a detective you may see some excitement, but you would also see that most detective activities involve in such routines as spending long hours observing people and filling out forms.

This is a problem in trying to study careers; what is on the surface is not the full picture. Being an engineer seems quite appealing when one views the challenges of problem solving and learns that many well-paying jobs exists for engineers. However, becoming an engineer requires a lot of hard schooling plus an aptitude and strong interest in the courses one must complete in engineering schools. Beginning your analysis early about careers is wise and will help you arrive at a well-considered choice.

The following general procedures should aid your search:

1. When watching educational films, observe the jobs portrayed.
2. Occasionally glance at newspaper ads to determine the types of positions available, the requirements, and salaries.
3. Ask relatives and acquaintances about their jobs.
4. Watch for news stories about job trends, contributions made by workers, and conditions in various jobs.
5. Be alert for people who are working in your area on construction jobs, in service positions, or any place where the opportunity to ask questions develops, most people like to talk about their work.

Next, follow the procedures below for a more systematic, in-depth occupational analysis:

1. Begin with a class discussion centered around this instructional module.
2. Use school, public, and college libraries, counseling centers, and personal interviews, when possible.
3. Develop a **career lattice** like the one shown here for a manufacturing engineering; however, choose an occupation of your interest.

Some people talk about career ***ladders,*** but we use a lattice, like one a rose grows on. Most careers have many ways to move through them in the manner much like a rose vine climbs a lattice. Next to each level place the education normally required to reach that level. Post the various career lattices for class discussion.

Math-Science-Technology Interface

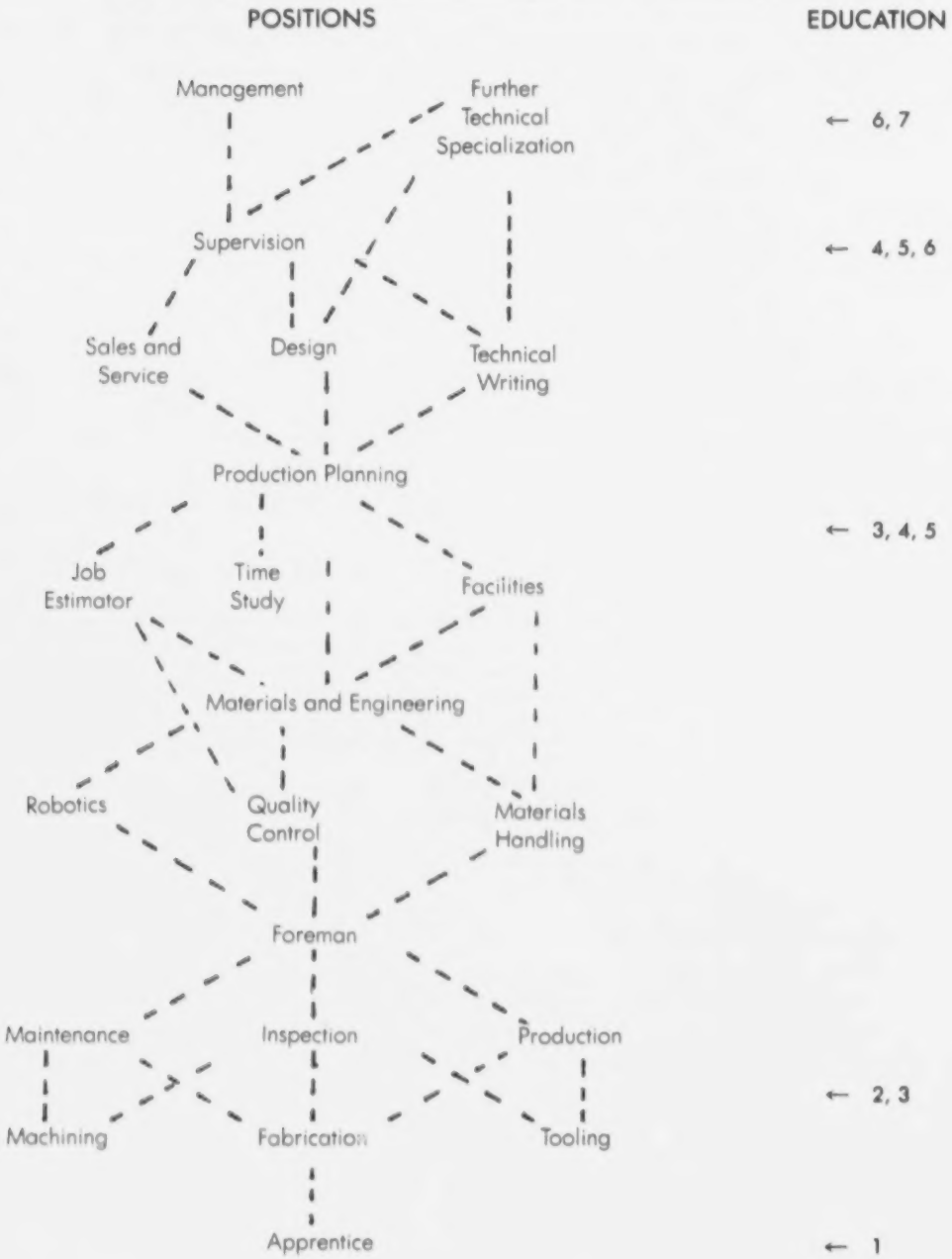
In studying the differences in the kind of preparation to enter various positions on the engineering team, you will see that some positions require more math and science than others. Figure 1 provides an indication of this relationship. It is *quite* important, however, to understand fully the prerequisite courses in math and science for entering the program of preparation for a given position on the technological team. This information may be obtained by talking to counselors and studying the brochures and catalogs on programs of your interest.

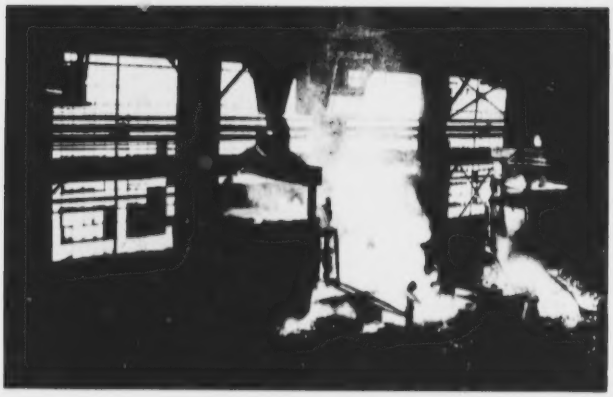
Career Lattice in Manufacturing Engineering

Figure 7 depicts a career lattice in manufacturing engineering. ***Position*** refers to the type of work involved in a certain area within manufacturing. These areas may include jobs for several members of the engineering team (e.g., technician, engineer, or crafts person). ***Education*** indicates the level of education normally required to enter these fields: 1–high school, 2–apprenticeship program, 3–associate of applied science, 4–bachelor of science in technology, 5–bachelor of science in engineering, 6–master of science, 7–doctor of philosophy. The broken lines —— between positions indicates the ability to move around on the lattice based on interest, experience, and success.

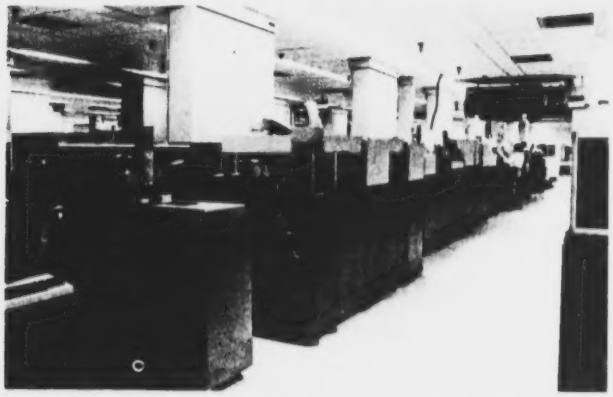
Experience acts as a key determinate that couples with education for the achievement of certain levels on any career lattice. In general, supervision and management positions provide for higher salaries, but with increasing need for technical specialization, those who distinguish themselves in their specialty should expect financial rewards on par with most management positions. Increased specialization may take the team member into research and development (R & D) or make them very valuable engineers, technicians, or scientists on several levels of the career lattice.

FIGURE 7
Career Matrix





This foundry with numerous craft people reflects the conventional factory of today. . . .



. . . It contrasts sharply with this ultra-modern manufacturing plant, labeled the "factory of the future." In this factory—that looks much like an office, the machines make semiconductor materials for computers.

Possible Student Outcomes

—Describe the technological forces that are driving changes in careers.
—List the members of the engineering team, give a short description of each, and name a job title for each member.
—Match the minimum education normally required for entry into positions on the technological team.
—Match the nature of work with members on the engineering team.
—List at least five fields of specialization within engineering.
—Construct a career lattice for a career that has a personal appeal.
—Locate and read references and consult qualified people to obtain career information.
—Develop values that relate to career preferences, and use those values in preparing for an occupation.

Student Quiz

1. Match the **minimum** educational level normally required to enter the four main positions on the engineering team.

(e)	scientist	a. high school degree
(b)	engineer	b. bachelor's degree
(c/d)	technician	c. AAS degree
(a/d)	crafts person	d. apprenticeship
		e. master's degree

2. Name four fields of specialization in engineering. (See Figure 2.)
3. For each of the four main members of the engineering team, list two job titles. (See Figure 3.)
4. List one of the forces driving changes in many occupations. *(Automation, increased world competition, advances in technology, changing qualifications for jobs, and a need for a stronger math- and science-based education by many workers)*

SELECTED READINGS

- *Accreditation Board for Engineering and Technology* (free pamphlet available from ABET, 345 E. 47th St., New York, NY 10017)
- *Careers in Engineering and Technology* (Brooks/Cole Engineering Division, 1984)
- *Careers in Engineering and Technology* (Macmillan Publishing Co., New York, NY 1984)
- *Dictionary of Occupational Titles* (U.S. Department of Education, Washington, DC, current ed.)
- *Engineering—Fundamental Problem Solving* (Brooks/Cole Engineering Division, 1983)
- *Engineer, Yellow Pages Career Library* (distributed by the National Association of Secondary School Principles, 1920 Association Dr., Reston, VA 22091, 1975)
- *Modern Talking Pictures Film Catalog* (for industry-sponsored free loan and videotapes, Modern Talking Pictures, 5000 Park St., N., St. Petersburg, FL 33709)
- *Journal of Industrial Technology* (National Association of Industrial Technology)
- *Occupational Outlook Handbook* (U.S. Department of Labor, Washington DC, current ed.)
- *Peterson's Guide: Engineering, Science, and Computer Jobs* (PO Box 2123, Princeton, NJ 08540)

REFERENCES

Brody, H. (May 1985). Automation U.S.A.: Overcoming barriers to automation. *High Technology*, pp. 41–46.

The Circuit. (1984, November/December). IBM East Fishkill: IBM pp. 2–8.

Drucker, P. (1985, March 26). A growing mismatch of jobs and job seekers. *Wall Street Journal*, p. 3.

Haavind, R. C. (1985, June). Technology's impact on the workforce. *High Technology*, p. 4.

NC/CAD/CAM Resource Center. (1985, January/February). *Commline: The Journal of Computerized Manufacturing*, pp. 27–30.

New York Times. (1985, October 14). Technological jobs to increase through 1995. p. 12.

Young, J. A. (1985, July). Meeting global competition. *High Technology*, pp. 12–14.

Acknowledgments

Figure 5 was reprinted with permission from IBM's The Circuit, (East Fishkill, Nov/Dec 1984, p. 5).

Other illustrations were furnished by American Iron and Steel Institute, AT&T Bell Laboratories, IBM Corporation, and the Forest Products Laboratory of the U.S. Department of Interior.

Resources in Technology

Before 1455, books were rare, precious possessions only the rich could afford. Scribes worked for months to produce a single book. Then, with the introduction of printing in the 15th century, each press could print as much work in a day as a copyist had taken a year to produce. Within ten years the price of books had dropped drastically and the way was open to mass communication.
(Language and Communication, 1968)

New Developments in Printing

Contemporary Analysis

Combining the invention of ink and paper by the Chinese and the development of moveable type printing by Gutenberg, the developed world was introduced to the art of printing around 1450. Since that time human ingenuity and new developments in technology have continued to improve the printing process. These improvements included refinements in papermaking and ink production, the steam and rotary presses, linotype, lithography and photography.

Today our printed world is produced using many processes. The leading reproduction process continues to be lithography (42%) with gravure (22%) and letterpress (18%) following. Newer processes gaining in market share include screen, ink jet, collotype, electrostatic, and flexography. Last year alone the printing industry generated an $84 billion business (Gottschall, 1981, p. 225).

In the past, most printing began with the writer using pencil and typewriter. Illustrations were developed by artists and photographers. Layout persons used rubber cement, blue pencils, T-squares, and layout pads. Typesetting was accomplished by hand set type, linotype, and phototypesetting. Then the plates were prepared by photoengravers or printers. Printers finally reproduced the story writers' ideas and the end product was delivered by the postal service or private delivery.

Today this process is changing and will likely change again in the very near future. With new technologies, data could be input by voice commands to computers or input via keystroking. The same computer terminal will be able to generate or pull up digital photographs or illustrations from its files. Again the copy will be able to be edited and made into pages on the same terminal. This data will then be able to be sent electronically via microwaves to printers who will reproduce the data directly electrostatically or convert it to plates to run on their four color presses. In other instances of limited distribution, the information will be sent and received electronically. These new revolutions in the printing industry are described in Table 1. The remainder of this "Resources in Technology" will describe these new technologies in printing and how they can be applied in the technology education laboratory.

New Technologies

When analyzing the new technologies being applied to the printing industry they may be categorized according to their stages in the generation of printed matter. These include creating, input (text and images), filing, composition, editing, production, and distribution.

Creating

When one prepares to compose a written document a combination of steps must occur. First the idea or the content of the work must be focused in the writer's mind. During this process old and new knowledge is combined and organized. By using new technologies in this process, the writer can gather old knowledge from existing data bases. Simply put, the writer sits down at a computer terminal and retrieves data (knowledge stored in existing computer files). Scanners also make it possible to search electronic documents for key words in data searches. This new process also saves the time of visiting various libraries to "track down" existing knowledge on the subject of writing.

These data bases are referred to as digital/electronic libraries and have been in use in the fields of medicine, agriculture, science, and education for the past 15 years. Often they are referred to as "computer searches." Companies also have these computer filing systems available for in-house data. Payroll, accounts, and distribution are a few of the items usually electronically stored for future use.

After the writer accesses old knowledge and plans how to integrate it with new knowledge, they begin to compose their document. Today this is done on computer keyboards instead of writing with pencil and paper. The key to today's composition is the interfacing that is available between the text and illustrations and photographs.

Today's technology is creating digital picture files. These files store photographs digitally and can be recalled when needed. They will replace file cabinets and folders as storage techniques in the future.

In addition, computerized charts and graphs are becoming available to the composer. Such developments as GE's' Genigraphics and Berthold's fps 2000 enable an artist/composer to combine color, typefaces, symbols, and layouts to create illustrations to accompany text. These can be electronically recalled and interfaced where needed.

Another development in the area of electronic illustration includes Dolphin's Computer and Electronic Design System. This system enables the illustrator to have visual options in his or her creating. With the computer terminal and screen of the system, it is possible to change the shape and appearance of letters to meet graphic needs. Letters may be rotated or stretched, and hard copy printed for layouts. Systems similar to this produce much of the graphic needs for today's television commercials.

As the above illustrations suggest, the entire area of graphic composition in the future will be computerized. The generation of text and illustrations in the printing industry will become computerized in the near future.

Input

With the changes in how documents will be prepared for reproduction in the future will come a need for new or retrained personnel in the printing industry. The new employee must know how to use a computer and graphic tablets plus make judgements according to quality of creations.

TABLE 1

New Developments in Printing

	YESTERDAY	*TODAY*	*TOMORROW*
Preparing a story, report, etc.	Pencil and paper, typewriter, dictation equipment	Yesterday's tools plus word processors and keyboard devices that deliver the copy for typesetter	The same terminal used to originate a story will be used to edit it, create illustrations, make up pages or areas, set type, expose the pages, bypass platemaking, produce multiple copies (collated) in color and using both sides of the sheet. It will be able to communicate to remote sites and distribute itself electronically when so desired.
Illustration—art/ photography	Pens, inks, cameras, etc.	As before	
Design/layout	Drawing table, pencils, T square, layout pad, ink, etc.	Yesterday's tools plus electronic interactive input and makeup devices, as well as programmed formats	While not everyone will need such an all-in-one machine, all sorts of combinations of multipurpose devices will be possible and available.
Typesetting	Foundry type, metal machine and phototypesetting	Photographic digital-CRT and digital-laser typesetting via typesetting services and in-office installations	In sum, all steps will be digital/electronic, and the systems will be affordable across a wide budget range.
Platemaking	Done by photoengravers or printers	More platemaking done in-house	
Reproducing (printing, binding, etc.)	Commercial printers, binderies, etc.	More printing done-in-house	
Distribution	U.S. Postal Supervisor, private delivery services	Increasing rise of electronic mail and competing transmission services and networks	

Developed from *Graphic Communication '80s* by Edward M. Gottschall, published by Prentice-Hall, Englewood Cliffs, NJ (1981), p. 54.

Today's data is entered through keyboards directly from the writer's mind or after it has been composed by pen and paper. For those that still rely on hand written or typed copy, there exists OCR (optical character recognition) devices that can read or convert text into electronic signals. This development saves enormous amounts of time in the composition process. This process saves time in additional keystroking and can be used to typeset previously printed materials. Newer models of OCR devices can even read handwritten documents.

The graphic tablet has become a supplement to the keyboard for data entry. With it an operator/composer can change typefaces, draw boxes, change letter spacing, and add symbols. With this device a light pen can be used on the tablet to indicate changes in the formating of pages. With such an easy-to-use device, those who are not trained can easily manipulate text to change it into a pleasing graphic format.

Scanning will be the main input method for entering illustrations and photographs into an electronic text. The scanning device will be similar to a TV camera with a laser as a light source. This will eliminate film, half-tones, T-squares, stripping, and opaque. Screening of photographs will be done electronically. All in all, electronics and computers will provide the input data for the total composition process in the near future.

Filing

After the writer has written their text and composed accompanying illustrations, the document will be filed electronically prior to formal composition. Traditionally this information was typed and illustrations collected and then filed manually until it was ready for printing. This would be similar to the writer composing this "Resource in Technology" and mailing it to the International Technology Education Association for composing, editing, and printing.

With electronic filing our text could be filed electronically on a disc either in Norfolk or sent via telephone to Reston and then be recorded on a disc. This process can eliminate much of the need for file cabinets and clerks in the future. A file that is electronically prepared may be stored and retrieved magnetically whenever it is needed in the printing process.

Composition

With the text and illustrations of an article, paper, ad, or document input into an electronic system, the next step in the printing process is composition or electronic pagination. In this step the text and illustrations are moved around for visual location and text is put into proper size.

There are many such composition machines appearing on the market today. Larger options range from $60,000 to $150,000. However with lower costs coming from less expensive microprocessors, composition machines such as Compugraphic's AdVantage and Itek's Graphic Display Terminal are ranging from $20,000 to $35,000 (Gottschall, 1981, p. 87).

These pagination machines incorporate the latest electronic tools such as the electronic pen, graphic tablet, electronic drawing board, keyboard, and electronic storage. The pen is used to select commands on the graphic tablet (markup board) to change the location or style of the makeup of the page. This page could be an ad (illustration and text) or it could be the front page of a newspaper. If a drawing is to be added to the text, it is traced from the drawing board using the electronic pen. New text or editorial changes can be added using the keyboard.

After the page is ready (composed as you want it), it can be stored in the electronic memory for actual typesetting. Again you can see how advanced electronics and the computer are changing the printing industry.

Editing

After pages of books, newspapers, magazines, ads, or other printed work are composed, they must be edited for clarification, style, and errors. The editing process has happened with pencils, typewriters, and typesetting (cutting and pasting) in the past. The newer way of performing this process is with a video display terminal (VDT).

Here the writer/composer/editor will, by the strokes of a keyboard, be able to correct errors, delete copy, insert new copy, transpose copy, reformat the material, or merge one piece of text with others. Again the computer, with its keyboard and electronic capabilities, will revolutionize this important process for the printing industry. With these developments enormous amounts of time; error, and money will be saved.

Typesetting

Typesetting represents a major conversion step in the production sequence of preparing printed materials. You have read about "hi-tech" composition and editing with VDT equipment, however, typesetting uses the electronically stored data and converts it into "hardcopy" that can be used for paste-up, make-up, or direct-plate production. The ledding of lines, justification, font selection, line width (measure), and point size is performed by a typesetter. During the editing process the electronic text is coded for the appropriate typesetting requirements. These codes are "imbedded" in each line and specify exactly what the typesetter is supposed to do (See figure 2).

This means that the typesetter will interpret this as being Century Schoolbook, 18 point, quad left and the second line is 24 point, quad left, and accordingly would print this on photographic paper suitable for paste-up.

The typesetting codes are not limited to text material but can incorporate borders, rules, circles, arcs, lines, reverses plus many other creative typesetting techniques. This appears to be complicated, but terminals that are used for typesetting have unique keyboards that greatly simplify the process of entering the typesetting codes.

The electronic file with the typesetting information encoded can be used locally in the production process or "mailed" electronically via telephone line, microwave link, or satellite to a distant location for further processing. Since it is stored electronically (magnetic media) it is available for use immediately or at a later time. Electronic typesetting equipment is generally linked to the "front end" (where the initial data entry is made) via modems, multiplexers, and cables and is called interfacing.

This task becomes difficult when a number of different brands of equipment are used as industry standard communication protocol and formats are just beginning to emerge. Additionally, older equipment did not have sufficient on-line memory to handle large editing and typesetting requirements. The trend today and in the future will be towards integrated systems that can handle the "creating, editing, and typesetting" functions as a stand-alone unit.

Production

The "first wave" in graphic communications can be identified as the invention of hot cast moveable type. The introduction of cold composition can be thought of as the "second wave" of innovation in graphic communications and the "third wave" can well be the impact of microprocessors and computers. The influence of technology is pervasive in that all areas of graphic communications have been affected. It is obvious that electronics has had a significant impact on the preparation of copy; however, changes in the materials, tools, and processes in graphic communications have been affected by science and technology also. Lasers, ink jet printers, xerography, microwave transmission and chemistry are drastically changing the methods and materials used for graphic products.

The major production categories in lithographic communications include composition and layout, paste-up, line and half-tone photography, color separations, stripping and proofing, plate making, production printing, finishing operations, and distribution. As mentioned earlier it is possible to by-pass and combine a number of these divisions. Today, however, large scale production volumes still use the basic departments and processes assisted by new technologies. Thus, these divisions are still significant.

Composition

As mentioned earlier, traditionally writers and artists prepared material manually. Typewriters and art aids (rules, brushes, templates, masking films) were the "tools of the trade." The text and artwork were later typeset by hot or cold composition and the artwork was changed into "color separations" by photographic methods.

Today, and with increased sophistication in the future, the writer may prepare text at a VDT, merge it with the work created by an artist at another VDT, paginate and format the material, and send it to laser printer for printing the final copy or platemaker for the preparation of press plates. The important concepts here are increased productivity and creativity.

The typography is being done by keyboarding information into a computer, not by a linecaster or counting keyboard, but rather the writer and the artist. A highly trained operator is generally responsible for writing the typesetting formats and "media-to-media" conversion tables to produce high quality typeset material. Thus, the overall result is that the quality of the typeset material is more a function of software control than operator skill.

Photography

The photography/darkroom processes are witnessing major revolutions and competition from new and emerging technologies. The new technologies represent laser scanners that produce printable plates from electronically stored media. Conceptually, this is consistent with the trend of "electronic publishing." Laser scanners can be used to scan single or multiple- color prepared artwork to produce half-tones and color separation negatives. Linework may be reproduced in a like manner. All may be produced from a single machine automatically. Microprocessors make the appropriate density and exposure calculations, and process an electronic film negative without a darkroom, tray developers, or running water. The pro-

FIGURE 2

A slight change in the codes imbedded in the manuscript produce different appearing type.

CODED ENTRY	TYPESET COPY
"f151}"p12}Technology Education"ql}	Technology Education
"f151}"p24}Technology Education"ql}	Technology Education

cessing time is shortened substantially and manual evaluation of copy, process camera set-up, and darkroom processes is eliminated.

Chemistry continues to provide many significant advances in the development of prepress materials. For example, film and photosensitive products are the mainstay of lithographic processes. The film characteristics must be consistent and reproduce fine detail, yet have some latitude in the operator's exposure, development, and chemistry.

Silverless polymer materials are making their way into lithographic processes. These are polymer materials that are sensitive to special forms of light and do not require light sensitive silver emulsions. While still fairly new, these products are making inroads into areas traditionally held by silver emulsion products.

As the price of silver increases these products are certain to become more attractive. The polymer materials are processed with single unit processors that speed processing and reduce costs.

Rapid access photosensitive materials have special synthetic emulsions that allow for high temperature (100°F) processing with short developing times. The processing times for rapid access materials ranges from a 1 to 1-½ minutes from start to finish (dry-to-dry), thus camera department personnel can produce a wide range of line, halftone, and contact materials and get high quality results with reduced time.

Additionally, diffusion transfer materials are available in positive, negative, and clear film materials for making positive and reverse stats as line or screened halftones. Here again, processors with "built-in chemistry" provide very short processing times eliminating the "deep tank" expensive processors of the past, thus adding to the vast array of prepress materials for fast and efficient production.

Plate Production

Plate production has been a labor intensive production area. Research efforts continue to provide new developments in this area to reduce labor costs and skills needed to produce press plates. Many of the highly-skilled decisions are, and will be made by microprocessors in the future. The measurement of film density was one of the first areas to "feel" the impact of electronics. Initially small hand-held densitometers were used to evaluate highlight and shadow details in preparation for making screened negatives.

Today electronic previewers and scanners evaluate original art or transparencies, and by simulation, monitor the total production process. That is, they consider process color separation, color correction, paper color and characteristics, ink properties, and press and production speeds to provide a high degree of quality control. Again it is microprocessor and "software intelligence" (which may be in solid-state memory device called a PROM) that enables this level of machine coordination.

Projection platemaking and automated page imposition will require less highly-skilled labor and provide for increased efficiencies. Computer-controlled camera technologies, now in place, will allow the use of one-piece film flats for multiple page presses from a computer-stored format. When coupled with projection platemaking capabilities with built-in precision and quality control parameters, automatic pagination will have an even greater impact on the efficiency in the platemaking area.

Production Printing

While much of the technology in graphic communications is oriented towards the prepress operations, such as composition and imposition, new developments are also occurring in the production area. Printing press manufacturers are adding sophisticated electronic controls to monitor production. Microprocessors monitor processes such the number of impressions, ink quality and quantity, moisture and ink rates, and quality of the printed output.

For example, a press operator would "punch-in" the weight of the paper, bond, book, index, etc., the number of copies desired and begin printing. The press would print the job at the optimum impressions per hour (i.p.h.), monitor the progress and provide a printed production record of the job number, paper quality, paper grammage, sheet size, print time, number of wasted sheets, when the job was started and completed. Smart presses also monitor mis-feeds and paper "jams."

In other words automation is managing many of the operations required of a skilled press operator. Additionally, presses are being linked with computers that manage the entire production process, from the magnetically stored "data," laser prepared plate, to the printed copy as it comes off the press.

Gravure printing processes will continue to expand because of their positive advantages including the simplest of all printing systems, easy press control, extremely fast operation, long runs, and the highest quality of any of the major printing processes. Currently the diffusion etch process of cylinder preparation is the most widely used. However, microprocessor-controlled laser scanners are making inroads in the preparation of gravure cylinders. The technologies for gravure are just emerging. Future projections are bright for this volume production process in printing technology.

Distribution

The printed products that "come off" the presses require some form of finishing. The finishing may be as simple as wrapping the product in wrapping paper in reams (quanities) of 500. However, most jobs require some form of binding or padding. The changes at this end of the production process has not experienced the same level of innovation as has the other production areas.

Prior to 1800, the process of bookbinding was slow and labor intensive. The press sheets that were to make-up a books were folded by hand with a "bone knife" and assembled into signatures that would later be stitched together to make a book. Browse in your school library and think "How long would it take to bind all of these books?"

The most common finishing operations are cutting, folding, assembling, and binding. Other operations include perforating, embossing, scoring, and die cutting. Each of these operations require accuracy as most all printing jobs involve more than one sheet of paper. Pages must be trimmed with precision and gathered in the correct sequence or order.

Today we see automated machines that perform the finishing operations in minutes that took many hours and even days and months to do in the past. Computer and calculators are used to figure the optimum yield of paper stock and hydraulic paper cutters cut paper effortlessly and with precision.

Folding, gathering, and collating press sheets into signatures is done by semi-automatic or automatic machines almost as fast as they can be printed. Stitching machines stitch signatures together for casebinding (e.g. a hardcover book), where in the past these processes were done entirely by hand.

Other binding processes include adhesive, side, or saddle binding. Each of these techniques involve new processes and technologies such as automation and the use of new types of adhesives to increase production.

Activity

Simulating Electronic Publishing

There are a number of ways to simulate the electronic publishing business in the technology education laboratory. The simplest way is to use a personal computer, dot-matrix printer and spirit duplicator (optional thermal copier).

Conceptually, the computer serves as the VDT/typesetter, and requires a word processing program for text entry. If graphics is desired then a suitable graphics program may be added. Text material is prepared with the computer and word processing program and stored by the computer on tape or disk media. Any graphics development that is desired would be prepared by using a graphics editor or graphics program. When the copy has been prepared and edited it is then printed using a matrix printer and a "spirit master."

The spirit master is then run on a spirit duplicator in the usual manner. Alternate methods include the use of "direct image masters" for offset printing and traditional paste-up methods to produce graphics and text layouts that can be used to make thermal spirit or electrostatic masters.

The personal computer opens up many new avenues for creativity in font selection and graphics. There are many software programs available for Apple, Commodore, IBM, and Tandy computers. One such inexpensive software program is called "The Newsroom," published by Springboard Software. The program includes all facets of the "electronic newsroom" such as the copy desk, layout, wire service, and printing press. This program simulates many concepts that are used by newspapers and news magazines such as "USA Today," "U.S. News and World Report," and "Time." Features can be prepared in remote locations and transmitted electronically to various geographic locations for printing and distribution by using the "wire service" feature of this software program.

A suggested activity is to prepare a newspaper/newsletter that brings together information from several AIASA clubs or schools to a common location for printing and publication. Classes from each of the "remote offices" would transmit "electronic files" via a personal computer and modem. The central office would edit and format the copy and prepare makeups for the press runs. The publication would then be distributed by normal methods. This activity represents a "graphic communication production" activity that would involve a number of graphic processes and illustrate contemporary technology.

FIGURE 3

Electronic publishing activity

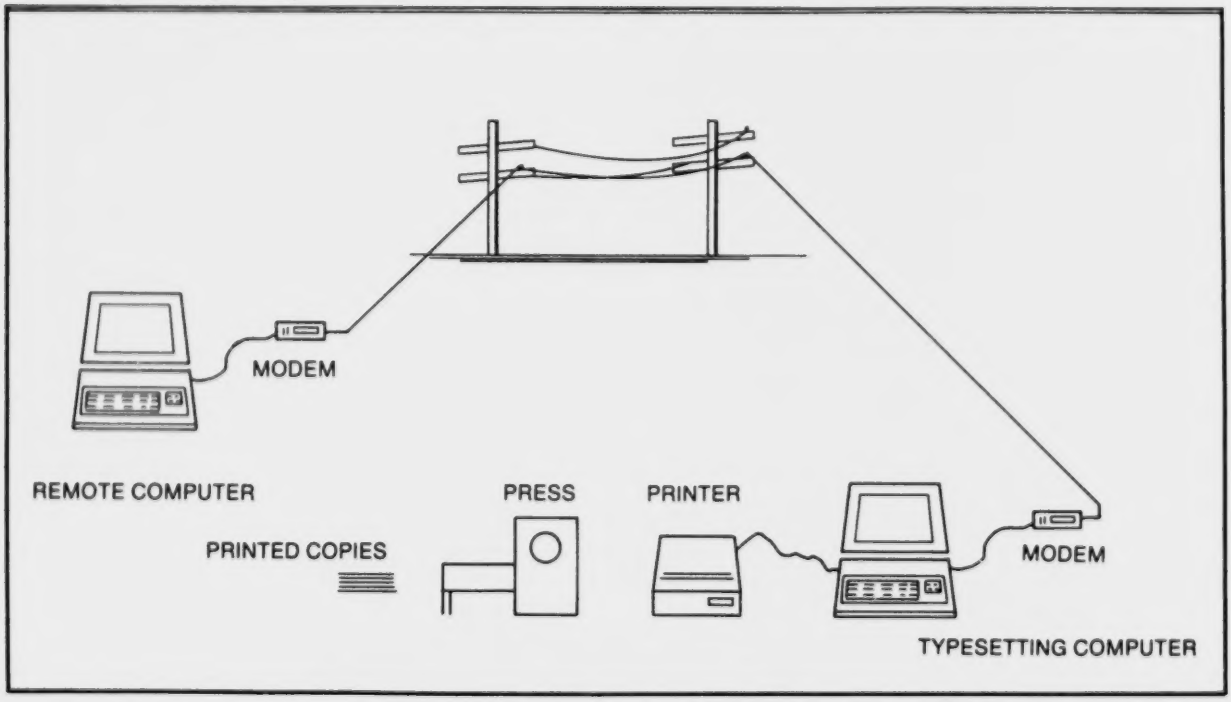
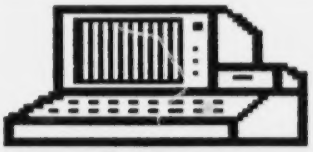


FIGURE 4
Sample newsletter

ComTech



January 1986 Volume No. 1 — Tidewater Technology Associates

USIA Regional Conference

The first regional conference for university students in Industrial Arts Education was held at the Virginia Beach Hilton from February 21-23, 1985. The conference was sponsored by a new association of Virginia college students who chose the name USIA (University Students in Industrial Arts). David McGuigan, the first president, hopes the organization will promote technology education and help strengthen student's leadership and organizational skills on each campus.

The conference began with exhibits by major publishing and equipment companies. These included Amtek, Bergwall Productions, Brodhead-Garrett, and Glencoe. Each college also prepared a table display of projects from their school. Displays ranged from industrial materials to a computer numerical controlled lathe. Computers were available for demonstrations of CAD and educational software.

On the following day Technology Education supervisors from the region provided workshops on curriculum, management, budgeting, and interviewing. During the afternoon a tour of NASA in Hampton was available for the students and supervisors to observe new technology.

On Saturday special interest sessions were provided by students from various colleges and universities. The presentations included Profitable Products, activities for members of ITEA and AIACSA, ways to sponsor events on campus and how to start a club.

Keith Gurley, a senior at Old Dominion University, introduced Professor Walter Deal who gave a telecommunications network presentation. The second conference is again scheduled for Virginia Beach in February 1986. For more information contact Tim Whitestone, who is a national USIA officer and senior at Virginia Polytechnic Institute and State University, Blacksburg, Virginia. Dr. Arvid Van Dyke is the state advisor for USIA and may be contacted for information also. Dr. Van Dyke is located at James Madison University in Harisonburg, VA.

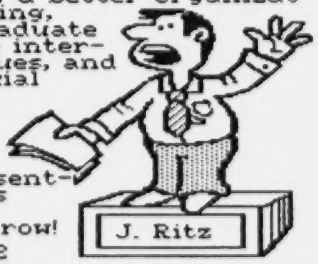
As a final note, the conference was a tremendous success as it was late Sunday when everyone reluctantly departed for their "home" university. Contest will be held again this year and everyone looks forward to bringing home those impressive awards that are highly prized!

Second USIA Conference

Late news up-date! The Program for the Winter USIA Conference has been published and is available from Dr. Arvid Van Dyke. The conference dates are February 20-22, 1986. The Hilton Inn, Virginia Beach Virginia will be the conference center. Registration will begin at 3:00 pm until 9:30.

The program includes university and commercial exhibits and industrial tours to local industries. Special presentations will be made concerning resume writing, job interviewing, lab management, teaching methods, and technical up-dates.

Club presentation seminars will focus on special interest sessions for USIA students. These sessions will include presentations and group dynamics in "sucessful club meetings, fund raising, building a better orgainzation, resume writing, planning for graduate school, effective interviewing techniques, and many other special interest topics.



Local, state, and national leaders will be also making presentations to today's emerging young leaders of tomorrow!

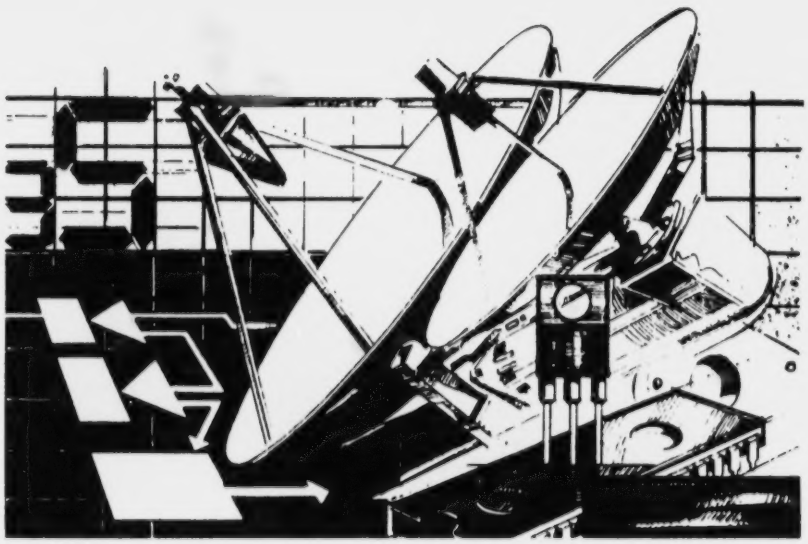
February 20-22

Summary

As you can see, the world of electronics in making a broad impact on the social, cultural, and technological aspects of graphic communication. Computer technology has changed the manner in which printed materials are prepared and printed. Composition and layout, photography, and production processes involve the extensive use of computers and microprocessors to greatly increase productivity and reduce costs.

It is anticipated that major segments of the printing industry will continue to expand. These areas include commercial printing, newspapers, business forms, and book printing and publishing. The production processes that are likely to expand are gravure and lithography.

The skills that are needed today and in the future will demand highly trained men and women that can process information electronically. Entering and manipulating data through the use of computers to produce graphic products. The activity that accompanies this article simulates the major concepts of today's electronic publishing industry.



Quiz

1. About what year were Western societies introduced to the art of printing?
   a. 1000 c. 1776
   b. 1450 d. 1957
2. Which printing reproduction method controls the market?
   a. letterpress c. screen
   b. gravure d. lithography
3. Outline the printing/composition process of the past.
4. Outline the printing/composition process of modern times.
5. What technologies have had the greatest impact in modernizing the printing industry? (electronics and computers).
6. What is an electronic file?
7. A machine that can read typewritten copy to typeset or compose it is called?
   a. optical character recognition
   b. scanner
   c. graphic tablet
   d. graphic display terminal
8. Describe the three waves in graphic communications.
9. Describe the concept of electronic publishing.
10. List three advantages of the new technologies to the printing industry. (cost effective, speed, and quality).

Possible Student Outcomes

- Describe the historical development of the printing industry.
- List the major reproduction methods currently used in the printing industry.
- Compare the composition/printing steps done in the past with those of today.
- Describe the use of electronics and computers in the contemporary printing industry (changes should be noted from creating through distribution).
- Apply contemporary printing technologies to classroom/laboratory activities to produce an "electronic newsletter."

References

Adams, J. & Faux, D. (1982). *Printing technology*. (2nd ed.). Scituate, MA: Breton Publishers.

Gottschall, E. (1981). *Graphic communication '80s*. Englewood Cliffs, NJ: Prentice-Hall.

Language and Communication. (1968). Philadelphia: The Curtis Publishing Company.

High tech typesetting. (1984). Alexandria, VA: Intergraphics, Inc.

Composite Materials

Introduction

This instructional module continues the series on engineering materials technology. The first module, entitled "New Materials," appeared in the May/June 1985 issue of TTT, followed by "Nature and Properties of Engineering Materials" in the December 1985 issue.

These modules provide an introduction to engineering materials especially if *Engineering Materials Technology* (see Acknowledgments) is used as a resource, since it provides many tables, illustrations, and applications of materials plus numerous references to additional resources.

Also, the *Materials and Processes Technology Instructional Resource Guide* from the Technology Education Service, Commonwealth of Virginia offers a guide to competencies on the subject. Such periodicals as *High Technology*, *Popular Science*, and *Discover* provide information on new developments in engineering materials technology.

The previous instructional modules on engineering materials developed concepts that will permit an understanding of the nature and properties of composites discussed here. Composite materials already have many applications and there is a continued increase in their use. The information here will aid you in becoming a wiser consumer of materials because you will look for certain properties in materials, whether composites or other materials.

For those who find this study interesting, many career opportunities await, including the study of design/manufacturing technology, materials science and engineering, welding and nondestructive testing technology, and electromechanical technology, to name but a few.

Social-Cultural Impacts

Composite materials are materials in which two or more materials, e.g., epoxy plastic resin and glass fibers, are combined to provide a desired property superior to the properties either of the individual materials might possess. Composites are normally combined at the *macroscopic* scale, which is easy to see with the unaided eye, as contrasted to alloying or synthesizing, which occurs at the *microscopic* scale. Refer back to the May/June, 1985 module, "New Materials," to see the basic structure of common composites. Composites are not new engineering materials. Ancient builders learned that adding straw to the clay used in making building blocks provided greater strength than the *monolithic* (single material) clay possessed by itself; early Europeans used hair from livestock to strengthen plas ter. Egyptians developed an early form of plywood. Mongol hunters in the thirteenth century constructed bows of a composite system of animal tendons, wood, silk, and adhesives; medieval swords and armor were made through laminating metals (Jacobs & Kilduff, 1985).

Composites have evolved to a point of great sophistication, and along the way laminated beams, plywood, bimetallic thermocouples, particleboard, cardboard, and many others joined our family of materials. Throughout society composites make contributions, including decorative laminated wooden beams in churches (Figure 1), homes, and offices; graphite epoxy tennis racquets, golf clubs, and fishing poles; plywood furniture, walls, doors, and roofs for buildings; fiberglass boats, aircraft, and automobiles; laminated plastic signs, toys, and art objects; clad metal coins (copper with 80% nickel alloyed on both sides of copper with 20% nickel alloy); boron-fiber-reinforced aluminum aircraft components; and laminated bimetal thermostat strips.

Advantages of Composites

In our definition of composites, we said that superior properties are developed by combining materials. This is the key reason for abandoning the monolithic material. Most often the advantage gained is in terms of the material's properties, such as improved tensile strength or stiffness, corrosion resistance, or a new electrical property,

FIGURE 1

Custom laminated wooden beams.

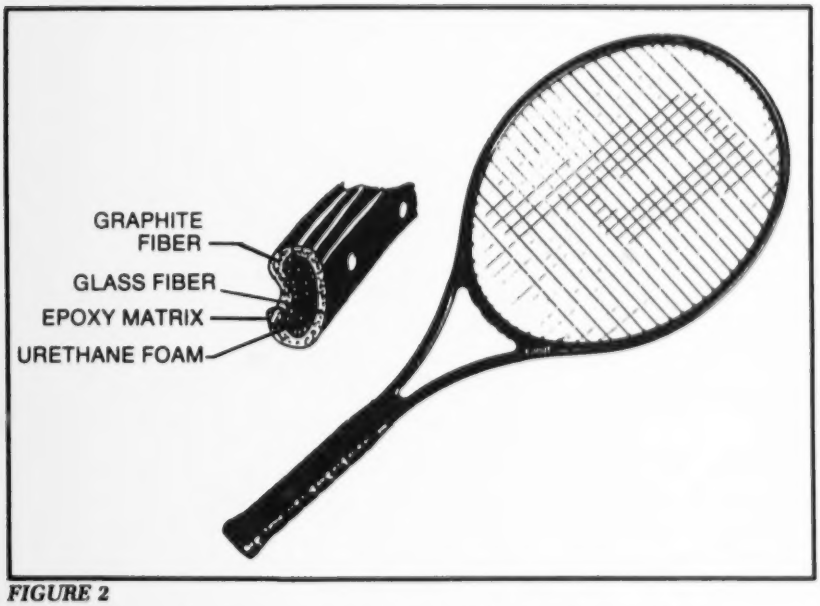


FIGURE 2

Tennis racket technology employs sophisticated advance composites.

such as that produced in thermocouples with thermoelectric coupling.

When most people think of composites they picture *fiber reinforced plastics (FRP)*. *Fiberglass*, which is probably the most common FRP, is generally referred to as *GRP (glass reinforced plastic)*. Two major advantages gained with FRP are *specific strength* and *specific stiffness*. High specific properties in composites mean that there is a greater strength-to-weight ratio in the composite material than in monolithic material. This concept of strength to weight ratio is further developed in the "Math/Science/Technology Interface" section of this module.

Figure 2 shows a new type of tennis racquet. This racquet represents a clever application of engineering materials technology that started a revolution in tennis racquet technology. Howard Head developed a racquet that was not only radically different from the standard tennis racquet in size and shape but also had superior hitting capabilities. He also looked at new engineering materials and utilized special aluminum alloys, laminated wood, and a variety of FRPs to offer tennis players racquets with seven material choices to suit the feel each player preferred. Since Head's development, scores of tennis racquets have been produced that offer variations on his design. Today, it is rare to see a tennis player, either pro or amateur, using the old style wooden racquet.

The racquet in Figure 2 is a complex materials system with a frame made of epoxy over a polyurethane core that is wrapped with fibers of graphite and glass to provide stiffness with low weight; the handle is made of polyurethane foam wrapped with leather. Head's newly engineered racquet design departed so much from the standard racquet that he was able to obtain a U.S. patent on his design after proving its superior hitting ability (Jacobs 1985).

Figure 3 illustrates why FRP competes so well with traditional engineering materials, especially in aerospace, automotive, and recreational equipment. Specific tensile strength and specific modulus of elasticity (stiffness) of steel and aluminum alloys are not equal to the FRPs shown. Note that orientation of fibers greatly affects strength, as shown in the key for Figure 3.

Figure 4 depicts possible arrangements of fibers in their matrices with varied directional properties. Composites graphed in Figure 3 are *advanced composites* (products of new metallurgical, ceramic, and polymer technology). Their cost is many times that of steel but they cannot withstand the temperatures that steel can. Consequently, the weight savings must be an overriding factor to justify these higher cost materials.

On the other hand, glass-reinforced epoxy is often less costly. Glass-reinforced polyester is quite inexpensive and offers a considerable weight saving over most metals. Polymer based composites do not present the corrosion problems of steel.

Rising fuel costs have helped justify use of graphite epoxy in aircraft and GRP in automobiles. The Pontiac Fiero, shown in Figure 5, represents only a beginning in the use of GRP for body panels for cars, trucks and vans.

While FRP production cars have been around since the 1953 Chevrolet Corvette, the Fiero marks the introduction of reinforced reaction injection molded (RRIM) plastic and nonreinforced plastic (SMC, TPO, and RIM) panels mounted on a sheet steel "space frame." Manufacturing techniques as used on Fieros allow use of robots and other automated

equipment to produce high-quality, high-production vehicles.

Other advantages of composites include:

- Dimensional stability
- Improved mechanical dampening
- Increased chemical and corrosion resistance
- Increased toughness (impact strength)
- Decreased water absorption
- Decreased thermal expansion
- Reduced overall cost
- Improved design flexibility (Jacobs & Kilduff, 1985)

The advantages presented above focus primarily on FRP. Some of the same advantages hold true for metal, ceramic, and wood based composites.

Try This

Locate some plastic packing tape with fibers composited into the tape and tape without the fiber reinforcer. Compare their strength by placing a tensile load on each piece and pulling it until it breaks. To be more scientific in this experiment use the simple testing device shown in the May/June 1985 article "New Materials." If you have a universal testing machine, it can provide better comparative data on the tensile strength advantages of composites over monolithic materials. Be sure to use a gripping device on each end of the tape to ensure an even load distribution.

Structure and Applications

You can discover a wide variety of composite structures all around your environment, whether it be in the school, at home, on the street, or even out in the woods. Nature created some very clever composites and wood is one of the best. Wood, while considered a monolithic material, has a composite structure in that its cellulose fibers are bond together in a matrix of lignin. Hornets, certain birds, and some insects build nests by reinforcing natural matrices, such as mud or their own body secretions, with twigs or natural fibers.

Try This

Locate an old tire, tennis shoe, piece of carpet, or circuit board in a calculator. Disassemble or cut open the device or material in such a manner as to expose the internal structure.

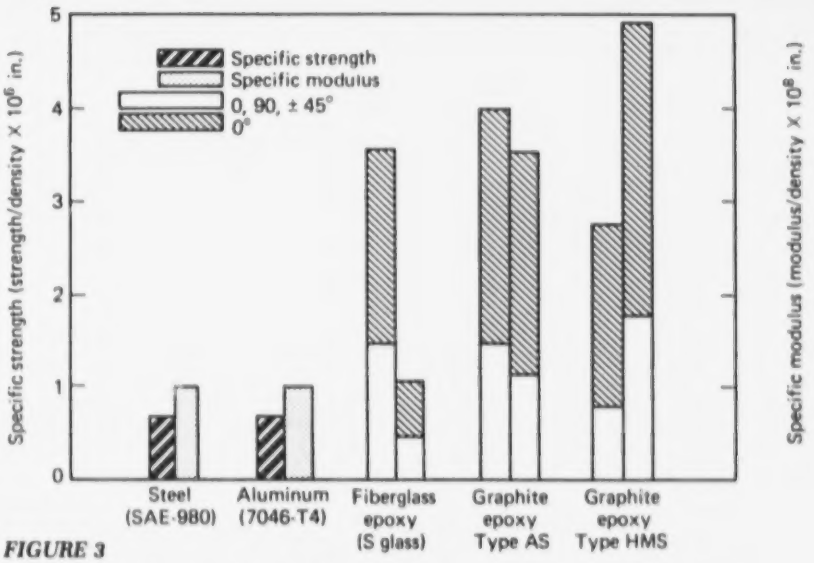


FIGURE 3

Comparison of specific tensile strength and specific modulus of elasticity (stiffness) of monolithic materials to advance composites.

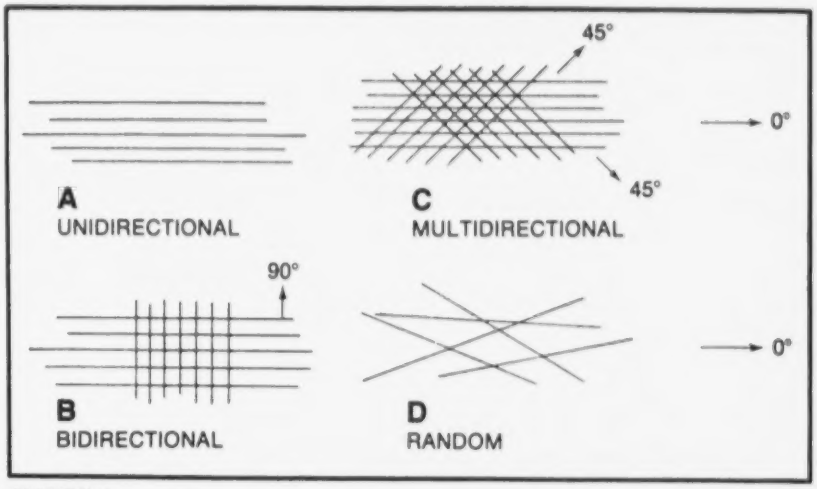


FIGURE 4

Various possibilities of fiber orientation in FRP.

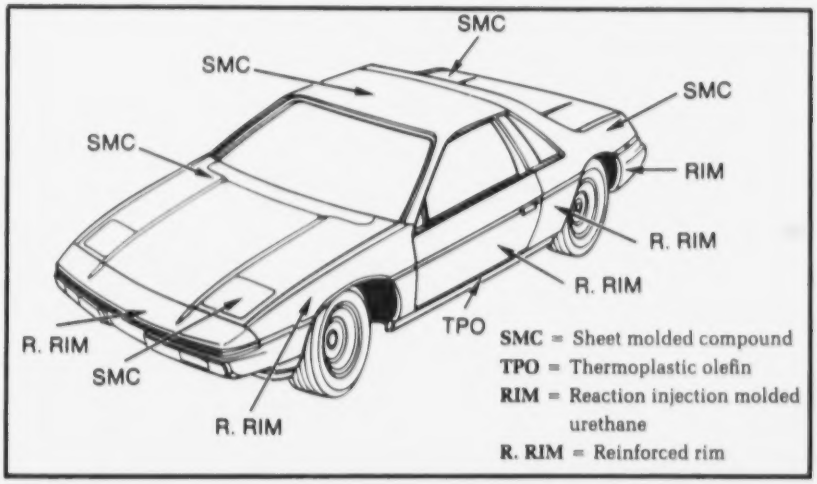


FIGURE 5

Pontiac Fiero uses steel "space frame" to mount plastic and GRP panels.

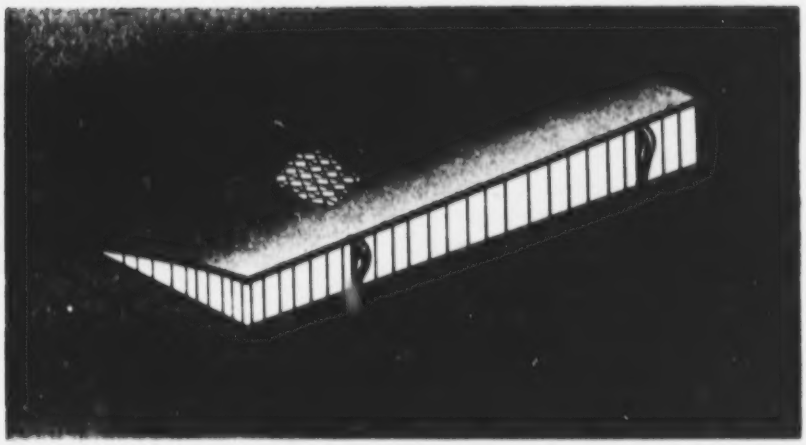


FIGURE 6

Honeycomb reinforcer in a layered composite using aluminum or advanced composite for aerospace industry.

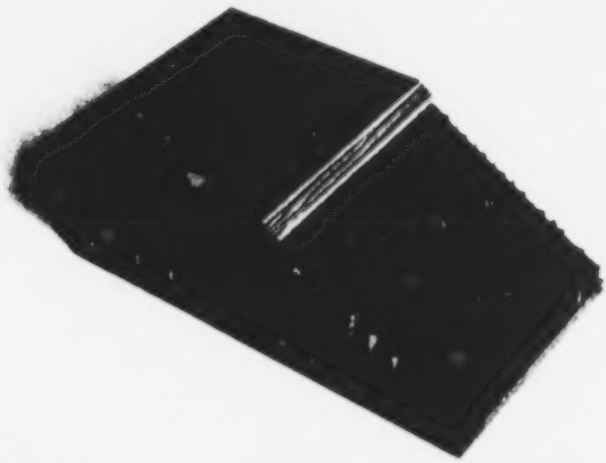


FIGURE 7

Honeycomb of heavy paper and plywood provides light-weight, high-strength and low-cost panels in building construction.

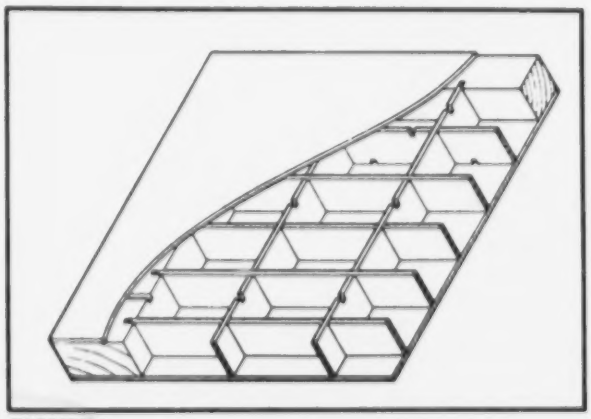


FIGURE 8

Hollow core layered composites.

Study the composite structure to determine the matrix, the reinforcers, and adhesive bonding system. Make a guess at the specific type of material used. Mount the component on poster board and label all parts for a nice display. Plywood is a good composite to work with. You can carefully remove layers so that each layer is exposed and grain direction is revealed.

The above activity will expose you to some composite structures but by no means all. The different structures are only limited by one's imagination. Most fit into the three main structures diagrammed in the "New Materials" module, namely layer, fiber, and particle. Others are usually combinations or variations of those three.

Layered Composites: The wings on the space shuttle *Orbiter* are an example of a variation of layered composites, as in the simplified diagram of Figure 6. A honeycomb aramid polymer forms the core, which is covered on top and bottom by sheet material. The actual shuttle wings are more complex.

Honeycomb cores (Figure 7) are frequently used in aerospace engineering because they provide tremendous strength with little weight, since the honeycomb is about 90% air. Most interior doors in modern homes are made with a variation of the honeycomb core; they are referred to as hollow core doors and use cardboard or wood, as shown in Figure 8.

Plywood is one of the most familiar layered composites. As shown in Figure 9, it consists of very thin veneers in which alternate layers have the grain turned 90% to provide uniform strength. There is no matrix in plywood; rather adhesives bond each layer together. Plywood is a subject that deserves considerable discussion beyond the space available in this module because of the large varieties. The veneers offer nearly unending possibilities, ranging from softwoods to hardwoods to plastics. The type of veneers and adhesives determines whether the plywood sheets can serve in outdoor, marine, or indoor uses and for either decorative or structural (heavy load bearing) purposes.

Fiber Composites: We have already devoted earlier discussion to FRP and GRP. Figure 10 shows still another application of GRP, as found in Corvettes since 1981. These glass fiber-epoxy resin composite transverse leaf springs provide a low stiffness and high design strength for the sports car while weighing 60% less than steel springs. Metal still meets needs for high temperature combustion parts (Jacobs & Kilduff, 1985,

pp. 392–393).

Even race car engines are being constructed of FRP. International Motor Sports Association racers use a four-cylinder thermoplastic plastic (trade named Torlon) with graphite reinforcement for engine blocks. These engines also use Torlon for many internal parts so that high strength plastic comprises about 63% of the weight (Plastic Cars, 1985).

Figure 11 shows another example of glass fiber in an epoxy matrix used to wrap an aluminum liner on a fire fighter's air breathing apparatus. This improvement over the older steel tanks provides for tank pressures up to 4000 psi and reduces weight by 47%, down 14 pounds. Such savings may be life saving, since the heavy weight of fire fighting gear can easily exhaust a fire fighter.

Rubber tires for numerous applications, from bicycles to wheelchairs to race cars and aircraft, represent sophisticated fiber reinforced rubber composite technology. Figure 12 reveals that tires are actually layered and fiber composites. To meet the tremendous stresses placed on the tires, which include high speed impact of landing 747 airliners, special rubber matrices are formulated, then reinforced with a variety of fibers. Fibers may be steel, glass, nylon, rayon, or aramid, with greatest specific strength. Aramid fibers sold under the trade name Kevlar is a high price, high performance advanced composite.

Kevlar reinforcing fiber material is a truly remarkable "space age" composite. It is used in bulletproof vests and suits for police, the President, and other dignitaries and in the newly-designed GI helmet; it is used to reinforce jet turbine engine blades and other high stress components on aircraft, spacecraft, and Formula 1 racers; and it forms the hull on ocean racing boats, canoes, and America's Cup sailing schooners.

Particle Composites: This group of composites is frequently found in ceramics as with concrete that consists of Portland cement forming a matrix that is reinforced with rock aggregate. *Cermets* are particle composites produced through *powdered metal* (PM)technology. This involves combining ceramics or *refractory hard metals* (RHM) with metals. Examples include tungsten carbide (WC), zirconia particles in an aluminum oxide matrix (ZrAlum O), and Sialon (silicon-aluminum-oxygen-nitrogen), which serve as cutting tools in places where high speed steel (HSS) is unsuitable, such as machining nickel based superalloys (Jacobs & Kilduff, 1985).

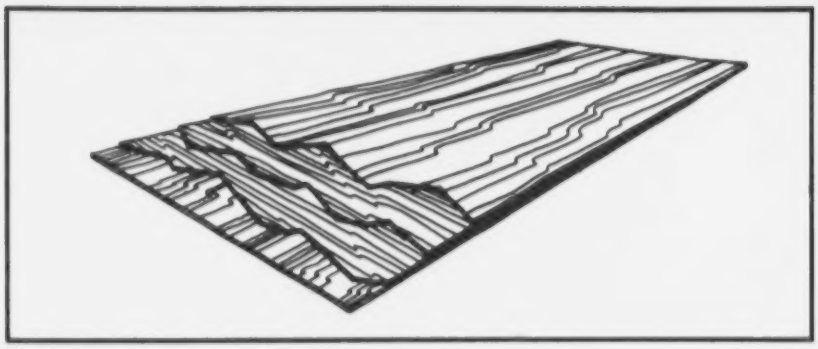


FIGURE 9

Plywood (layered composite) uses thin plies (veneer), with the grain turned 90 degrees on each ply.

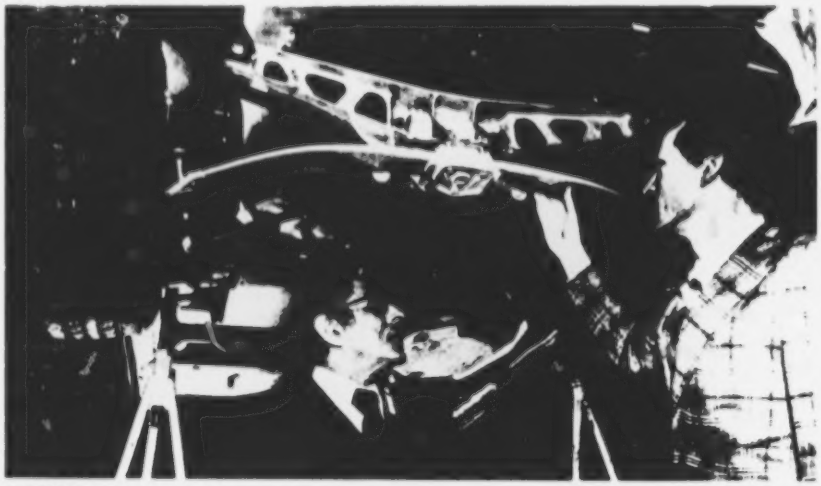


FIGURE 10

GRP for leaf springs on Corvette saved 60% of the weight over the older steel springs.

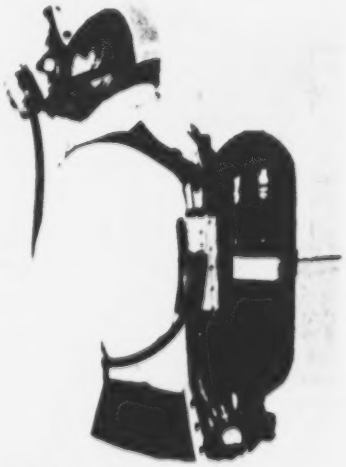


FIGURE 11

Fire fighter air breathing apparatus made of aluminum wrapped in glass epoxy saved 40% weight over older style steel cylinder.

Radial ply cords run straight from bead to bead with stabilizer belts applied directly beneath the tread.

FIGURE 12

Tire technology uses many composite structures.

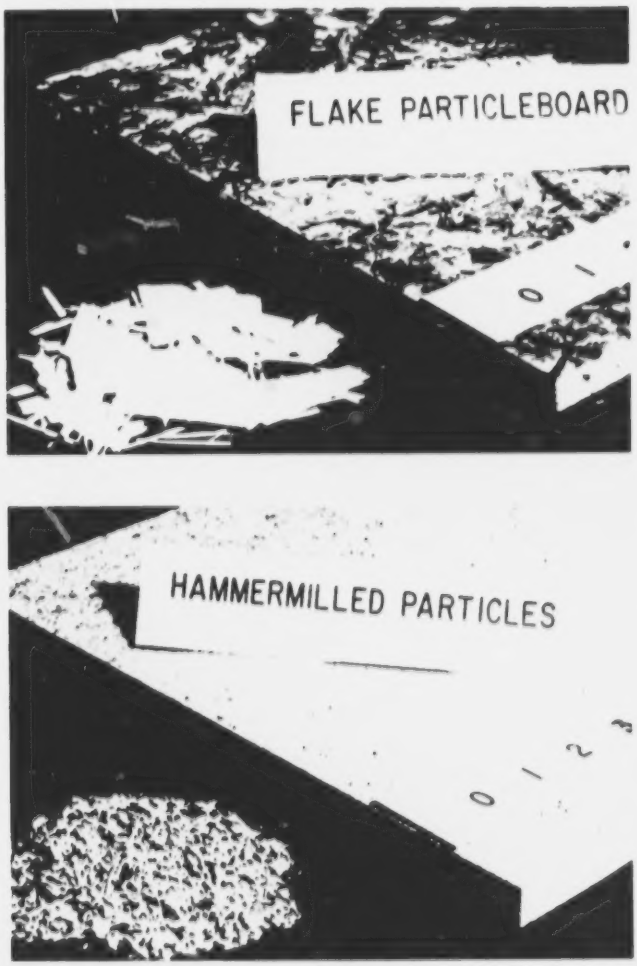


FIGURE 13

Particle composites include wood particleboard and flakeboard.

Particleboard is another example of particle composites. This expanding technology provides panels for furniture, building sheets, and many other applications. The advantage offered by this technology lies in the ability to get more from our forests.

Whereas monolithic wood and plywood require relatively defect-free logs, particleboard and its brother, flakeboard, can use limbs, knots, bark, roots, and most of the tree to produce flakes or particles, which are bonded together in a polymer matrix to form sheets (Figure 13). As with plywood the type of adhesive and wood determines whether the panels can be used for structural and outdoor purposes or whether they must be limited to interior and low load bearing applications.

Much of today's furniture uses particleboard cores laminated to veneers of hardwoods, softwoods, or plastics. This provides an economical alternative to solid wood and plywood.

We have provided you with some basic information on composites. If you want further information, refer to the bibliography.

M/S/T Interface

In this module we discussed advantages of composites over monolithic materials and used the concepts of specific strength and specific stiffness. Now we will explain these properties and show how to calculate them using both U.S. Customary units and SI units of measure.

Specific strength is the ratio of a material to its weight density.

Tensile strength provides an indication of when materials will fail under an opposite pulling force.

Density is the ratio of mass to volume, e.g., density of a cubic meter of wood at 12% moisture content is 0.68×10^3 kg $\times$ m^{-3}. The value of this property is in knowing how the weight influences a material.

Specific stiffness is the ratio of modulus of elasticity to the weight density of the material. Modulus of elasticity provides a measure of a material's stiffness or how difficult it is to bend. Stiffness is very important in such applications as driveshafts, wings, building framing, and tennis racquets.

To compare specific strength of steel

$$\text{SPECIFIC STRENGTH} = \frac{\text{TENSILE STRENGTH}}{\text{DENSITY}}$$

STEEL	GRAPHITE FIBERS
$= \frac{4.1\ \text{GN/m}^2}{77\ \text{kN/m}^3}$	$\frac{1.7\ \text{GN/m}^2}{13.8\text{kN/m}^3}$
$= 54\ \text{km}\ (54 \times 10^3\ \text{m})$	$= 123\ \text{km}\ (123 \times 10^3\ \text{m})$

GN = giganewton; kN = kilonewton; km = kilometer; m = meter

FIGURE 14

Specific strength of steel and graphite compared.

and graphite fibers, we apply the above formula and use SI units. We use weight density instead of mass density (Figure 14).

We see that the tensile strength of steel (4.1 GN/m²) is about three times as strong as the graphite fiber (1.7 GN/m²). Due to density differences, the specific strength of graphite fiber is about four times that of steel.

For another example, we use the U.S. Customary units to compare specific strength of aluminum with a GRP (Figure 15).

The glass-reinforced plastic is both stronger and lighter than the aluminum and yields a specific strength for GRP (1685×10^3 in) over three times that of aluminum (50×10^3 in).

Try This

Calculate the specific stiffness of steel with a density of 0.283 lb/in³ and a modulus of elasticity of 30×10^4 lb/in². Then convert to units to recalculate using the conversion factors for modulus of elasticity.

$$\text{SPECIFIC STIFFNESS} = \frac{\text{MODULUS OF ELASTICITY}}{\text{DENSITY}}$$

ALUMINUM	GLASS-REINFORCED PLASTIC
$= \frac{50 \times 10^4\ \text{lb/in}^2}{0.100\ \text{lb/in}^3}$	$= \frac{150 \times 10^4\ \text{lb/in}^2}{0.089\ \text{lb/in}^3}$
$= 50 \times 10^3\ \text{in}$	$= 1685 \times 10^3\ \text{in}$

lb = pounds; in = inches

FIGURE 15

Specific stiffness of aluminum and a GRP compared.

Construction Activity

In this instructional module, we studied three broad classifications of composites: fiber, layer, and particle. Constructing useful products with composites may be accomplished with tools and equipment found in most technical labs.

Layered composite products are easily made in several ways:

1) use chlorinated acrylic solvents to dissolve and bond together strips or sheets of acrylic of different colors and texture; then use heat to freehand or press mold the laminates into desired shapes;

2) use wood veneers, steam and pressure to form objects, such as bowls, archer bows, or bookends, then bond together with appropriate adhesives;

3) use contact cement to bond sheet plastics with solid wood, particleboard or plywood to make any number of decorative products, from clipboards to lazy Susans to skateboards.

GRP provides a means to make interesting fiber composite products. For example, Styrofoam packing material can be carved into desired shapes; then reinforced with woven glass cloth and resin. Use equipment to make expandable styrene bead products, then reinforce, with fiberglass. Most plastic suppliers can furnish required materials and directions for specific procedures; also use such books as *Fiberglass* by Gerald L. Steele.

Particle composite products may be made from either wood-based, ceramic-based, or metal-based materials using a die set up as shown in Figure . For wood-based products make a die of the desired shape even machining the ends of the punches. Extruded aluminum pipe or seamless steel pipe allows molding of large diameter objects. Spray mold parts with silicone parting mixture; then fill the female portion of the die with a mixture of sawdust and polyester resin (also vinyl, phenol, or resorcinol glues). Use bench vice, arbor press, or heated platen hydraulic press to apply pressure until the parts cure.

For metal-based powdered metallurgy products, obtain instructions and materials from technology education suppliers.

Local hardware and building materials stores can provide materials and instructions for concrete casting. Reinforcing wire is often required for adequate strength in concrete.

42

Quiz

1. Make a sketch to represent each of the following types of composites and label the matrix and reinforcer.
   a. concrete (see Figure 2)
   b. layered with honeycomb (see Figure 3)
   c. bidirectional FRP (see Figure 4).
2. How long have composite materials been used by humanity?
   (since early history)
3. Composite materials are contrasted with single materials, also referred to as __(c)__ materials.
   a. solid
   b. polymer
   c. monolithic
   d. high tech
4. The structure of composites is usually visible at the __(a)__ scale.
   a. macroscopic
   b. microscopic
   c. subatomic
   d. grain
5. Name one example of the following types of composites:
   a. FRP
   b. GRP
   c. advanced composite
   d. honeycomb
   (many possible answers; refer to definitions of each)
6. When weight savings is one of the most important design considerations, an FRP would be selected over steel because of __(d)__ .
   a. density
   b. tensile strength
   c. stiffness
   d. specific strength
7. Name two examples of a new use of FRP on cars.
   (several possible answers such as GRP Corvette leaf springs, RRIM panels on the Fiero, and thermoplastic/graphite engine blocks)
8. Name an example of composites with nonplastic bases for particle, layered, and fiber structures.
   (many possible answers—see definitions)

References

Jacobs, J., & Kilduff, T. (1985). *Engineering materials technology*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Plastic cars hit the road. (December 1985). *High Technology*, pp. 67–68.

Acknowledgements

Figures 1–4, 8–10, and 12 from James A. Jacobs and Thomas F. Kilduff, *Engineering Materials Technology*, 1985 reprinted by permission of Prentice-Hall, Englewood Cliffs, N.J.

Figure 5 supplied by Pontiac Motors.

Figures 6 and 11 supplied by the National Aeronautics and Space Administration.

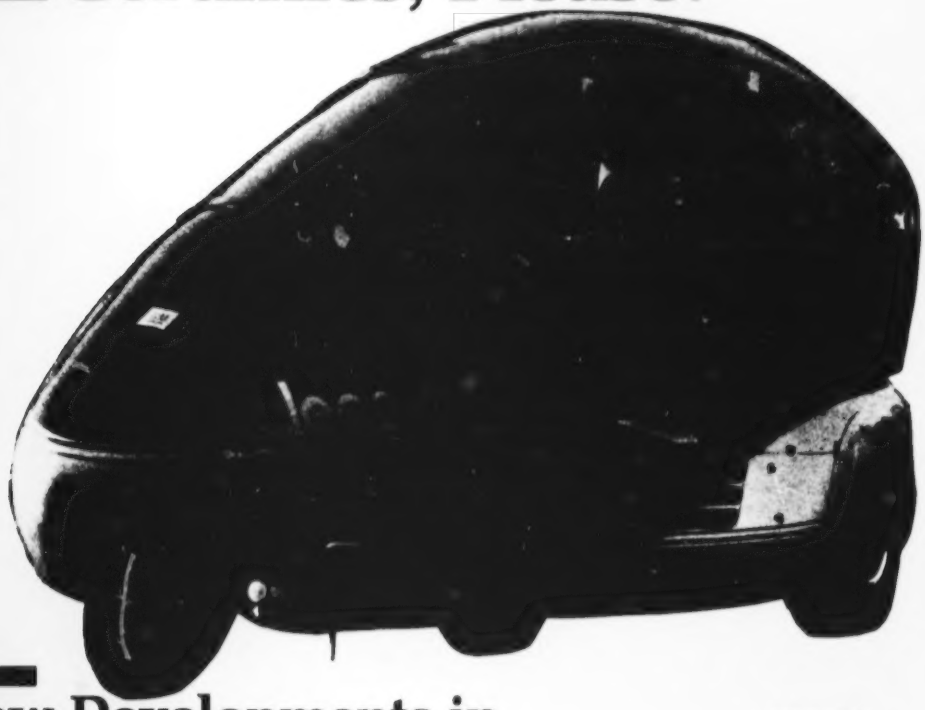
Figure 7 supplied by the U.S. Forest Products Laboratory.

Possible Student Outcomes

- Describe the value of composite materials to engineering and technology.
- Sketch and apply appropriate labels to composite structures (layer, particle, and fiber). Also label the matrix, reinforcer, and adhesive as appropriate.
- Define the following terms and cite examples: (a) FRP, (b) GRP, (c) advanced composites, (d) monolithic fiber, (e) matrix reinforcer, (f) RRIM.
- Explain how composites have contributed to humanity through the ages and in our modern technological society.
- Calculate specific strength and specific stiffness and then explain the importance of these properties.
- Construct useful composite products.
- Observe use of composite materials in everyday life and in special new applications.
- Analyze your personal interest in the study of engineering materials technology to determine if you wish to pursue further study in one of the numerous possible vocational or college programs.

Resources in Technology

"Check the Ceramics, Please!"



New Developments in Transportation

For the most part, the majority of the people probably take transportation for granted. The car is outside to use whenever they want to go shopping, to a movie, or on a trip. Airlines are available at nearby airports for any longer or faster trips they may require. As for transportation on the water, some people might be able to name one or two brands of their favorite fishing boats. Some might even be able to name a few famous oceanliners, such as the QE-II or the ill-fated Titanic. City buses, which they may have occassion to use, are a familiar sight on busy city streets. On any trip on the open highway, tractor trailer rigs can almost always be spotted moving America's goods from one point to another.

If, indeed, society's view of transportation is really as limited as indicated above, the entire field may roll right on by. In light of the many new developments in various transport fields, we should learn as much as possible about the continually emerging field of transportation.

The future of transportation may appear quite different than the way we have typically viewed it. Ten years ago, almost any knowledgeable motorist would have confidently predicted that electric cars were to be the wave of the future. Many of these same forecasters are not now quite so certain. Transportation technology is constantly changing and with those changes usually come new and exciting challenges.

FIGURE 1

The lean machine is perhaps the first new road vehicle developed during this century. The experimental three-wheeler, powered by a 30-hp engine, can accelerate to 60 mph in seven seconds and travel up to 200 miles on a gallon of gas.

Socio-cultural Impacts

Throughout history, changes have occurred that have affected the technology of transportation. About 1900 years ago, two "remarkable" new developments emerged to help man meet the transportation needs of that day. Each, in its own way, contributed to the further advancement of transportation technology. The earliest of the two, the rigid horse collar, replaced the previously used harnesses that tended to choke animals pulling heavy loads. The second, the iron horse shoe, enabled horses to travel further and faster without damage to their hooves.

Another development, still in the same field, was that of the whiffletree. It appeared about 1000 AD. It helped to distribute the weight of a coachload of passengers or wagonload of cargo equally among the pulling horses. This greatly reduced the risk of an overturned or unbalanced load, thus increasing safety safety.

Throughout the entire history of transportation, man has constantly sought new and improved methods, equipment, and modes to help him meet his transport needs.

The objectives of early developers were basically the same as those used by designers and planners today. Society still wants and needs to move people and goods with a minimum of undue jostling in the most cost-effective, safe, and expeditious manner possible. Transportation's developers have continued to refine its technology. Many developments today also seem truly "remarkable," but will probably seem no more so to future generations than the whiffletree does to us.

We now have sailboats without traditional sails, engines that have no cooling systems as we know them, and aircraft that have the distinct capability of circling the globe on one load of fuel. Many of the materials once thought to be absolute prerequisites for the construction or manufacture of various types of vehicles and components are now being replaced by polymers and composites. These may be lighter, stronger, more cost-effective, and much more dependable.

One welcome problem that is immediately obvious in discussing this topic is the vast number of significant new developments available for study. For our purposes, many will be mentioned here, but due to space limitations, only a few will be discussed in any detail. Additional information may be obtained by checking the materials listed in the bibliography and from your library. Further, almost any entity involved will be more than happy to supply information on new developments in transportation which are relevant to them.

With this brief overview in mind, let's examine some of the new developments in detail. We'll look at how they have impacted on the field already and how they may in the future. Many of the developments have applications in more than one area.

Rocket Belt

By taking a page straight out of Buck Rogers, Bell Aerosystems publicly unveiled a "small rocket lift device" at Fort Eustis, Va., in 1961. It marked the beginning of a totally new dimension in the realm of flight. It was the first rocket-powered system in the world which propelled man above the ground in controlled free flight (see Figure 2). Propulsion was accomplished using a hydrogen peroxide system. Using this backpack type device, the operator was able to propel himself in any chosen direction or to reach any given point and simply hover.

Since that initial demonstration, over 3,000 showings have been conducted throughout the United States, Canada, and on five continents. Similar devices may be commonly used to transport men over treacherous terrain on earth and are already used in our space program. The idea of astronauts exploring some hostile planet's liquid surface in the same manner as they have moved about on the lunar surface is not as far-fetched as it once may have sounded. A chair and a stand-up version have also been developed. The freedom of movement and the re-start capabilities of the rocket lift belt seem to offer unlimited potential future applications.

The "Rail" Truth

After developing from the old coal-fired, smoke-belching steam engines, railroads are now looking seriously at faster, quieter, and more economically feasible magnetic levitation vehicles, among others. This train, as the name implies, does not ride on a track, but above it. Although it is capable of speeds in excess of 200 mph, the magnetic levitation vehicle operates on a principle as simple as a toy magnet.

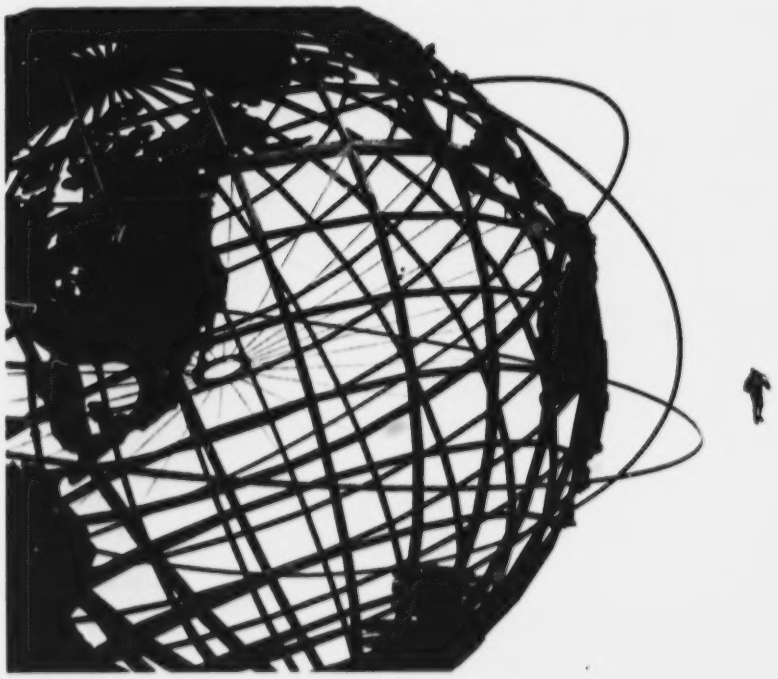


FIGURE 2

The experimental rocket belt carries this person on a solo flight.

This innovative power system may be compared to a three-phase synchronous electric motor. The stator is laid out in the track to provide the energy that turns the rotor. The train itself is the rotor, that part of an electric motor that actually moves. In a trial project, the Transrapid Project, two cars were used, each containing 60 very large magnets. Sixteen of the magnets were mounted on the sides of the cars positioned to point up toward the underside of the tracks where the stator packs were. These longitudinal flux magnets actually lifted (levitated) the train off the track. Each magnet produced a force of 1.8 tons. The remainder of the magnets, positioned along the sides of the cars, provided a magnetic flux perpendicular to the track and actually served to guide the train along. The 178-foot train utilized a conventional power source drawn from a 110-kilovolt line.

The test project, conducted in the early eighties, ran on a 20-mile track between Lathen and Doerpen in Germany. After its first successful run, the head German engineer denied that they have reinvented the wheel, saying instead, "We've abolished it" (Dornberg, 1983).

Several other designs for more efficient rail service have also emerged in recent years. High speed train travel has been a reality in Japan and France since the 1970's. These trains, or "bullets" as they are affectionately called, travel over 140 mph. Here in America, the California Bullet was planned to run between Los Angeles and San Diego. Congested traffic on conventional roadways made this an ideal location. A further route has been planned from Los Angeles to Las Vegas.

Regulations and the initial financial obligations continue to be considerable hurdles in the path of the Bullet at this time. The technology, mostly imported from Japan at first, is presently available however.

Polymerics

Polymers (plastics) were once used by the automobile industry only for cosmetic effects and steering wheels. Today they are the primary product in an automobile's interior. While in the past they were only rarely functional, polymers are being used today in doors, fenders, bumpers, and many exterior body panels. In the near future, Chrysler plans to offer a composite plastic spring in some of its models. The chassis and structural applications for polymers seems limitless.

Further testing and development are required to determine the parameters of the possible practical applications. One of the major limiting factors in the more extensive use of polymers is the lack of a sufficient data base from which to build. Test and performance data similar to that already available for metals has not yet been fully developed.

Composites

The wide acceptance and use of composites certainly merits an examination of them. "A composite material is a complex solid material composed of two or more materials that on a macroscopic scale form a useful material" (Jacobs and Kilduff, 1985).

Related to transportation technology, probably the most commonly known example of the application of composites is in the manufacture of steel belted radials and bias ply tires. Both are a part of our lexicon when we need a "new set of wheels."

Composites are a large portion of the wave of the future in transportation related manufacturing. "With the ever-increasing use of composites, they are truly the material of today and the near future, because they can be designed to be stronger, lighter, stiffer, and more heat resistant than other natural materials or to possess properties required by technology that are not available in a single material" (Jacobs and Kilduff, 1985).

When considering a list of the qualities of composites, the desirability of their applications in many transportation areas is immediately obvious. (Jacobs and Kilduff, 1985).

- To increase stiffness, strength, or dimensional stability.
- To increase toughness (impact strength).
- To increase heat deflection temperature.
- To increase mechanical dampening.
- To reduce permeability to gases and liquids.
- To modify electrical properties.
- To reduce costs.
- To decrease water absorption.
- To decrease thermal expansion.
- To increase chemical and corrosion resistance.

The extensive use of composites in our space program has not only produced multiple benefits there, but also spin-off to other industries. For example, NASA has shown the advanced use of composites in a new engine design. It incorporates a composite nacelle, fan frame, and fan blades. To list only a few of the many other applications outside of our space related industries, they are also used in the production of disc brakes, body and chassis parts, battery trays, fans, and one-piece steering columns.

Ceramics

Ceramics, long a part of the fixtures in our bathrooms, are now found in the engine manufacturing industries. The ceramic insulators in our automotive spark plugs are a long-used application of ceramics in the automotive industry and others. They are utilized because of their heat resisting characteristics. More recently, however, the more extensive use of ceramics in other engine areas has been under development by several major engine manufacturers. Ceramics have been used successfully in engines' heads, cylinders, valve guides and seats, and piston domes.

FIGURE 3

Polymerics are an increasingly important part of auto interiors.

Typically, the internal combustion engine loses much of its efficiency through heat loss. Much of that inefficiency may be overcome through the application of ceramic materials in heat-critical areas. Their use may also lessen the weight required in completed engines that are usually primarily heavy cast iron.

Another big plus for the use of ceramics is the availability of the raw materials required in their manufacture. Silicates, which make up many ceramics, are among the most common minerals in the world (Jacobs and Kilduff, 1985). When compared to those required in the manufacture of metals or plastics, the feasibility of the extensive future use of ceramics appears to be very favorable.

One of the more interesting recent applications of ceramics technology is in the area of space transportation. We have all heard or read volumes of commentary on the troublesome insulation tiles on NASA's space shuttle. Those little tiles have now been developed to the extent that they shield heat so effectively, a white hot ceramic block just out of a 1260°C furnace can be held on its edges with a bare hand (Jacobs and Kilduff, 1985).

Automobiles

During the next century, automobiles will probably continue to be man's primary means of transport. Trucks also will probably remain as our main form of over-the-road cargo haulers.

There will, however, be many technological improvements. Much of the required technology is already in existance. Although gasoline will probably remain as the fuel of choice, fuel mileage should increase greatly by the beginning of the next century. More efficient, equally powerful engines may be made of molded ceramics and lightweight metals.

With these developments, typical fuel consumption should be one-third that of today's vehicles. Commuter vehicles may even be powered by methanol fuel or electricity. Cars are planned that will run on both land and water and may use hydrogen as a fuel source.

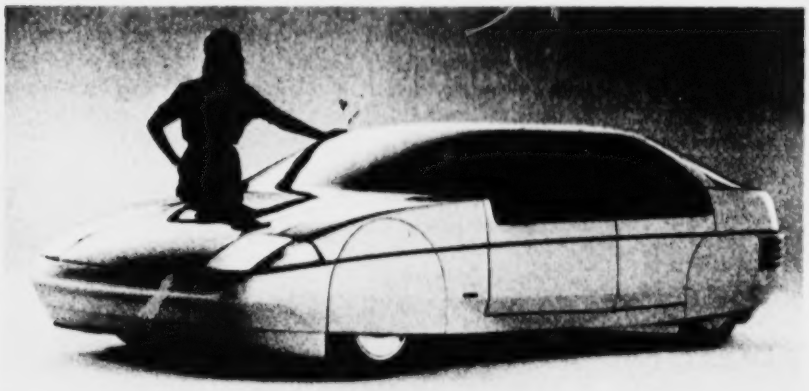


FIGURE 4

An emphasis on efficient use of materials will be the continuing hallmark of new car designs.

FIGURE 5

The development of electronics for automotive use will be another hallmark of the car of the future.

Fuel energy, a basic requirement for transportation, may even be drawn from our marine resources. Economic feasibility studies have been done on the production of gasohol via ethanol synthesis from marine photoplankton. This virtually untapped, yet readily available resource may be capable of supplying many of our future energy needs. Some of the studies have indicated that gasohol produced in this manner could be economically competitive with traditionally used gasoline.

Mass Transit

Mass transit on land will be designed to be more commuter-friendly and, thus, gain a more wide acceptance than it has previously experienced. Multi-sectional buses are planned that will seat as many as 150 passengers and operate on special busways. Fare collection will become more generally simplified through the more extensive use of electronically coded cards. Washington, D.C., and other cities have already implemented such systems.

Mass transit in the atmosphere will continue to experience positive changes. Jet liners are being planned that will carry as many as 1,000 passengers on long flights. That would be nearly double the number of passengers carried on even the largest planes today. Aluminum, long believed to be an ideal lightweight manufacturing material by the aircraft industry, may be replaced. Faster and lighter aircraft may be built using polymers (plastics) as well as graphite-epoxy composites and various metal fiber combinations.

Aircraft of the future will be designed using even more electronically controlled functions. Hydraulic controls may give way to electronic ones. Computers will probably do all the flying with a pilot along only for safety reasons.

Electronics

As it has been indicated earlier, electronics will permeate all fields of transportation. With this proliferation, our transportation modes will become faster, smarter, more cost effective, and safer. Electronics will monitor fuel consumption and give early detection of mechanical problems. Much of that technology is in use today, but it will be more finitely improved.

The vice president for design at General Motors has predicted that soon all the company's cars will be totally electronic. Such innovations as voice-actuated switches and radiotelephones will be standard equipment in all new

cars. Electronics will also control shifting, braking, shock absorbers, and suspension systems.

Again, much of this is already present, but will be refined to a much greater degree in the foreseeable future. One such bit of sophistication may be the long sought after, but very elusive, crash avoidance system. It will employ a microprocessor and sensors which will actually steer clear of trouble.

The widespread use of electronics will naturally contribute to the overall "slickness" of vehicles and directly address the American motorist's propensity toward more and more sophisticated equipment. Because of miniaturization, the further development of electronics for use in transportation seems inevitable. Plastics may have been referred to as 'the wave of the future, "but electronics has been labelled 'the deluge of the future." (Laginess, 1984)

Three main forces have contributed to the extensive use of electronics in the automotive and other fields.

1. Government's insistance on compliance with extremely stringent emission standards.
2. The search for better and still better fuel economy.
3. The availability of less expensive and more powerful computers.

Much of this extensive use has occurred as a result of spin-offs from the space program. The abundance of electronic wizardry and its implementation in space is nearly staggering.

Space Travel

Using electronics, the space shuttle will lead man upward for at least the next twenty years. Our permanent space station is expected to be in orbit in the 1990's. The shuttle will probably be used to ferry manufacturing materials up which require the relatively pure environment of space for more successful operations.

As many as 100 scientists and technicians may use the shuttle as a ferry to and from their work environments. The Space Lab, as it is now commonly called, will be the jumping off point for our future explorations in space.

Research stations will be established on the moon using "Space Tugs" for equipment and personnel movement. Space travel for the common man, however, is not predicted for any time in the near future.

Marine Transportation

Since 70% of the earth's surface is covered by water, man's technological expertise in the area of marine transportation has been truly challenged. Apart from the obvious advances in navigation (electronics) and more efficient traditional vessel design, other very interesting and unique developments have also occurred. We'll look at just two of the more innovative of these developments.

Although other models are available, we'll examine just one air cushion vehicle. It's the Lighter, Amphibian, Air Cushion Vehicle (LACV-30). The vessel is a high speed cargo carrier with a 30-ton payload. Capable of speeds up to at least 62 mph, the craft does not travel in the water, but above it. It was developed by Bell Aerospace for the United States Army to serve as a lighter to ferry cargo from ship to shore where no suitable port existed. Its civilian uses, some already proven, multiply when you consider that the air cushion vehicle is capable of operating on or from 70% of the world's beaches.

The craft might be employed in any of the following ways:

- Ferry boat
- Search and rescue
- Medical and evacuation
- Augmentation of fixed ports (it requires none)
- Operations over water, land, snow, ice, and marsh

In addition to being operational in any of the situations listed above, the air cushion vehicle is also impervious to

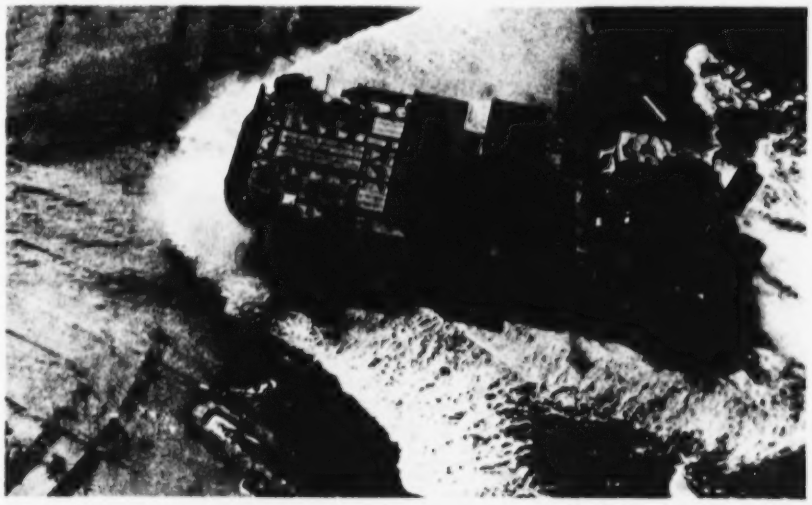


FIGURE 6

The LACV-30, one of the new air cushion vehicles.

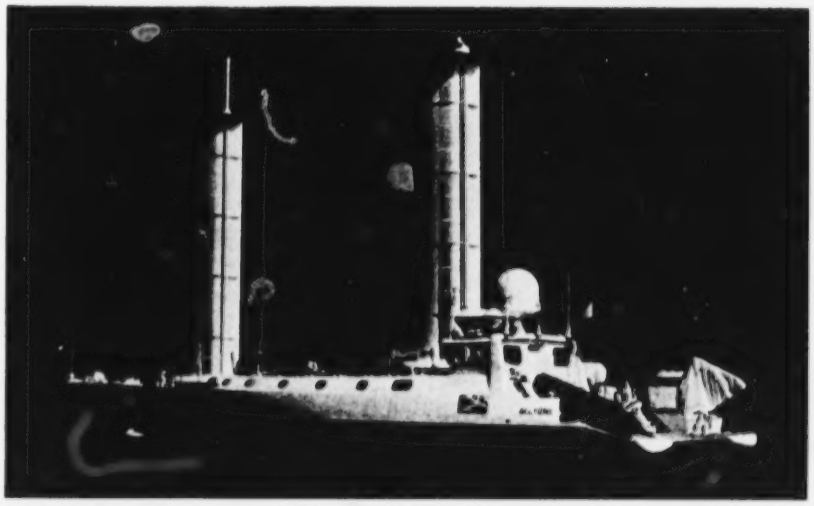


FIGURE 7

The Cousteau-Pechiny Turbosail merges the technologies of aerodynamics and hydrodynamics.

hot or cold weather, can plunge through eight-foot surf conditions, and go over four foot obstacles. The craft is powered by two gas turbine engines and uses standard jet fuel, which is available nearly worldwide. Its future growth potential seems certain.

Finally, let's examine briefly a revolutionary development in a water-borne transportation modes. It is indicative of some of the radical innovations in transportation technology.

On June 17, 1985, a new vessel "sailed" into New York harbor after a successful crossing of the Atlantic Ocean. Its journey had been mainly powered by the wind, using the Cousteau-Pechiny Turbosail™. The arrival of the ship represented a merging of the technologies of aerodynamics and hydrodynamics.

"The system operates on the same principle as a conventional sail, yet with heightened efficiency, achieved through combining the capability of a sail to orient to the wind with the aerodynamic principle and design of an airplane wing." *(Calypso Log)*

Using the lift principle involved in aircraft flight, the new sail design and its shutter-flap system causes the vessel to move forward (Figure 5). Two 156 hp diesel engines can be used to augment the Turbosail™ system or during periods of no wind. The resultant fuel savings on a voyage of any length is substantial.

Admittedly, we have barely scratched the surface in this brief article on transportation's new developments. Further readings are listed at the end of this article. Now we'll look at a construction activity.

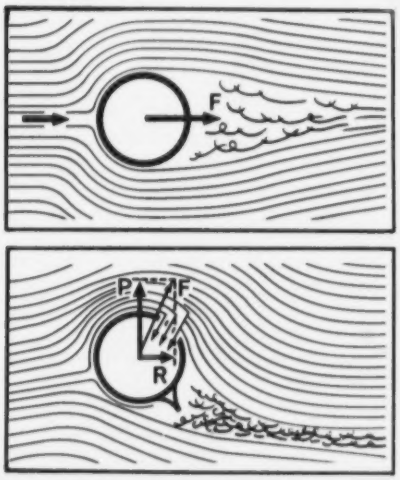


FIGURE 8

Two schemes illustrating how the Turbosail vessel moves forward.

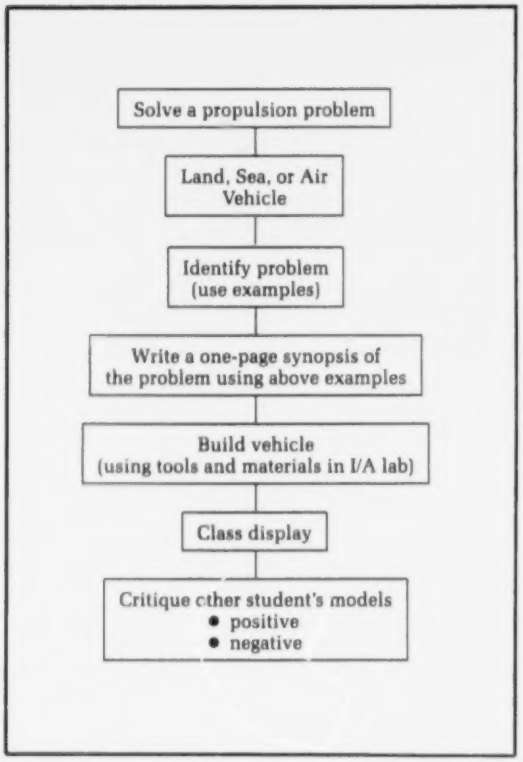

Solve a propulsion problem
Land, Sea, or Air Vehicle
Identify problem (use examples)
Write a one-page synopsis of the problem using above examples
Build vehicle (using tools and materials in I/A lab)
Class display
Critique other student's models
• positive
• negative

FIGURE 9

Technology project diagram.

Construction Activity

Now that we have surveyed several of the new developments in transportation technology, you can try and make some of your own. The authors of this series strongly believe that the practical application of materials learned is the most effective teaching device. For this activity, education in this phase of technology education should take place in a suitably equipped lab. A hands-on project will be used to reinforce the material covered in this article. The focus of this activity is to use tools and materials found in the industrial arts/technology laboratory (wood, metal, synthetics, etc.) to develop a new transportation vehicle.

Sample

Problem: Our natural energy resources are being used at an alarming rate by our traditional transportation modes. Design and build a model utilizing an alternate propulsion system.

Research areas:

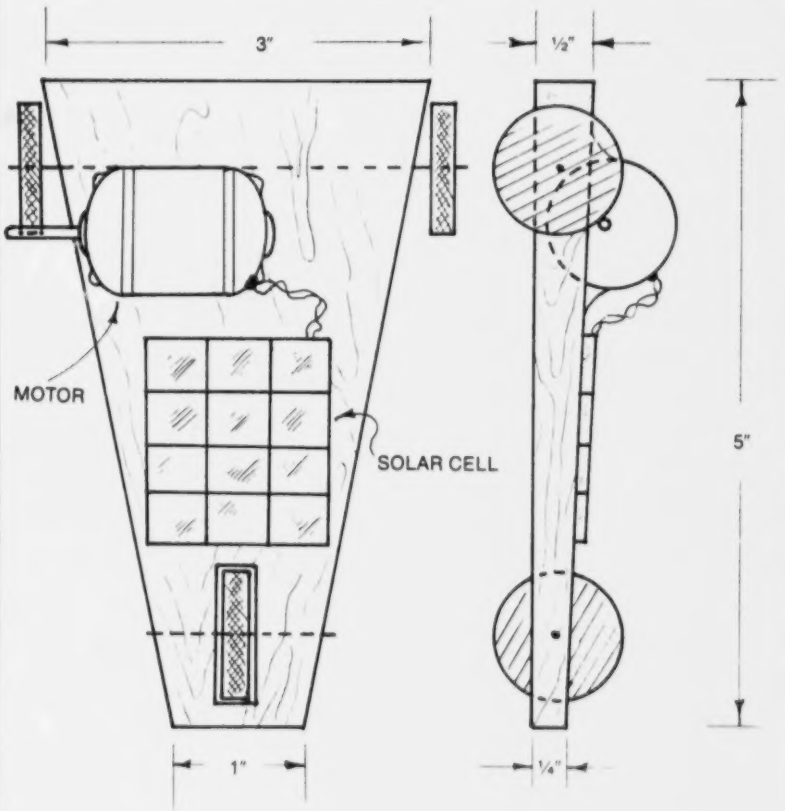
A. Present propulsion fuels (gasoline, JP-4, etc.)
B. Alternate propulsion systems (wind, solar, etc.)
C. Present manufacturing materials
D. Alternate manufacturing materials

Selected solution (based on research)

A. Light weight land vehicle
   1. Lightest practical materials
   2. Strongest practical materials
B. Small solar powered motor
   1. To drive wheels?
   2. To drive 'push' fan?
   3. To drive both?

Research limitations

A. Vehicle to be tested outside on a sunny day
B. Measured distance utilized
C. Speed checked
D. Scale: ½" to equal 1'



Materials List
- Body material (indicated by research)
- Solar energy project set, Radio Shack #277-1201 (includes DC motor and solar cell)
- Three suitable wheels
- Axle material (piano wire)
- Transmission (geared 30 to 1) or motor shaft could be set to friction drive the rear wheels

FIGURE 10
One possible solution to the construction problem.

Class presentation (give a two-page report on your vehicle)

A. State the problem
B. Support the solution chosen
C. Tell about vehicle built
D. Give and support conclusions

This activity shows that activities in technology education can address contemporary technological problems. However, to better understand how various technologies may impact on our lives, one must have an understanding of mathematic, scientific, and technological principles. The next section of this article explains this interface, relative to transportation technology.

M/S/T Interface

Technology education provides an excellent environment to introduce and implement mathematical and scientific concepts and skills to solve technological problems. The following example will help to illustrate this relationship.

A newly designed internal combustion engine had many experimental concepts incorporated into its fuel system. The engine was mounted on a test vehicle. It successfully moved the test vehicle along a straight line, but engineers were in doubt as to the acceleration characteristics that were exhibited. An acceleration test was performed and the following data resulted.

Acceleration increased steadily from 18 meters per second to 32 meters per second in seven seconds. Although this seemed significant, engineers wanted to determine just what the actual acceleration rate was and to put it in workable terms.

Acceleration has been defined as the rate at which the velocity of a body changes, which in our case is the test vehicle. For the vehicle moving in a straight line with a constant acceleration, the engineers found the actual acceleration rate by dividing the change in the speed of the vehicle that took place during a given time by the time. If V_o represented the speed of the vehicle at the start of acceleration and V was the final speed acquired after being uniformly accelerated for a time t, the constant acceleration a was represented mathematically as follows:

$$a = \frac{V - V_o}{t}$$

Substituting their data into the formula gave this result:

V equalled 32m/s

V^o equalled 18m/s

t equalled 7s

$$a = \frac{V - V_o}{t}$$

$$= \frac{32\text{m/s} - 18\text{m/s}}{7\text{s}}$$

$$= \frac{14\text{m/s}}{7\text{s}}$$

$$= 2\text{m/s}^2$$

From the resulting data ($a = 2\text{m/s}^2$), a determination was made regarding the changes in the test vehicle's fuel metering system. This was done by comparing the new data to that obtained from the testing of the engine prior to those changes.

This rather simplistic problem clearly shows the interface that exists between mathematics, science, and technology. Many similar and more complex tests are made constantly by those working to improve our technology. Each test, no matter how simplistic, serves to add to our constantly growing wealth of technological expertise.

The following quiz may be used to check for your student's understanding of this unit. Prior to concluding the unit, remind students that countless books, periodicals, and articles are continually being written and revised because our technology is changing so rapidly.

Quiz

1. Which of the following is a new development in transportation technology?
   A. diesel engine
   B. mass production
   C. composites
   D. steamship
2. Transportation technology
   A. is constantly changing
   B. has changed little recently
   C. is basically unchanged since 1903
   D. changes at regular intervals
3. The wind-powered ship, Alcyone, employs the principle of
   A. thrust
   B. ergonomics
   C. rapid mass transit
   D. lift
4. The Alcyone intergrates the technologies of
   A. thermodynamics and aerodynamics
   B. hydrodynamics and aerodynamics
   C. aerodynamics and flight
   D. solar power and wind
5. A magnetic levitation vehicle rides
   A. above the track
   B. below the track
   C. free of the effects of gravity
   D. on overhead cables
6. During the next century, man's primary mode of transit will probably be the
   A. magentic levitation vehicle
   B. mass transit system
   C. PRT system
   D. automobile
7. Now being used extensively, polymers are more commonly known as
   A. composites
   B. plastics
   C. ceramics
   D. synthetic metals
8. Projected sources for future fuel needs may be
   A. aquatic
   B. solar
   C. terrestrial
   D. all of the above
9. The air cushion vehicle
   A. has only military applications
   B. actually rides on the land's or water's surface
   C. has not yet been successfully tested
   D. could be utilized on 70% of the earth's beaches.
10. The air cushion vehicle
    A. requires ideal sea conditions for satisfactory use
    B. uses standard jet fuel
    C. is adversely affected by temperature changes
    D. is useless over icy areas
11. Which of the following statements regarding ceramics is false?
    A. they may lessen the weight required in completed engines
    B. Their future use in engines is in doubt due to design problems
    C. raw materials for the manufacture of ceramics are limited
    D. all of the above
12. A useful complex solid material composed of two or more materials defines a
    A. compound
    B. mixture
    C. composite
    D. hybrid
13. Which of the following is not a desireable quality of a composite?
    A. reduced cost
    B. increase thermal expansion
    C. increase corrosion resistance
    D. modify electrical properties
14. Although many facets of transportation technology may eventually affect the development of a crash avoidance system, which of the following will probably do so to the greatest degree?
    A. composites
    B. ceramics
    C. ergonomics
    D. electronics
15. New developments in transportation have occurred
    A. throughout history
    B. only recently
    C. mainly on space
    D. on a limited basis

Resources in Technology is written and prepared by Tidewater Technology Associates (T2A) an educational consulting group that specializes in technical programs, curriculum and instructional development. Members of the organization are: John M. Ritz, Paul L. Cummings, Walter F. Deal, III, Martin M. Fray, W. Fred Hadley, and James A. Jacobs. Further inquiries can be made by contacting John M. Ritz, 5316 Marlington Drive, Virginia Beach, VA 23462; 804/440-4307.

Possible Student Outcomes

- List several new developments in transportation, giving examples.
- List possible other applications of the new developments in transportation.
- Describe at least one new development in detail.
- Analyze how transportation's new developments may affect future modes.
- Apply materials and scientific knowledge to the solution of technological problems.
- Associate math and science as an intergral part of transportation technology.

References

Dornberg, J. (1983, November). Will Maglev fly? *Popular Mechanics*. pp. 90–94.

How it works. (1985, September). Calypso Log. p. 14.

Jacobs & Kilduff. (1985). *Engineering materials technology*. Englewood Cliffs, NJ: Prentice-Hall.

Laginess, E. (1984, March 21). Speech delivered at the fourth U.S.—Japan automotive industry conference, Ann Arbor, MI.

Laying a U.S. track for high speed trains. (1983, April 25). *Business Week*. p. 49.

Marine Technology 80, 16th Annual Conference. (1980). Washington, D.C.: Marine Technology Society.

On tap, faster, easier, more comfortable travel. (1983, May 9). *U.S. News and World Report*. pp. 17–18.

Selected Readings

Moving on with mass transit. (1985). *The Technology Teacher*. Reston, VA: International Technology Education Association. 44(6), 19–26.

PRT: the way to go! (1986, February). *The Technology Teacher*. Reston, VA: International Technology Education Association. 45(5), 19–26.

Altschiller, D. (Ed.). (1982). *Transportation in America*. New York: H. W. Wilson Co.

Ceramic Materials

This instructional module continues the series on engineering materials technology. The first module entitled "New Materials" appeared in May/June, 1985 of TTT *followed by "Nature and Properties of Engineering Materials" in the December, 1985 issue, and "Composite Materials" in March, 1986.*

These modules should provide an appropriate introduction to engineering materials especially if Engineering Materials Technology (see Acknowledgments) is used as a resource since it provides many tables, illustrations, and applications of materials plus numerous references to additional resources. Also, the *Materials and Processes Technology Instructional Resource Guide* from the Technology Education Service, Commonwealth of Virginia offers a guide to competencies on the subject. Such periodicals as *High Technology, Popular Science* and *Discover* provide information on new developments in engineering materials technology.

Introduction

A study of ceramics will show why this ancient material has gained new respect and why its unique properties hold promise as engineering designers work to meet the demands of high technology.

During the coming years you will become a consumer of ceramics in ways never dreamed of in earlier engineering. Many of these applications will be hidden as they are today. For example, few people stop to consider that the insulator on spark plugs are made of glazed aluminum oxide. In the near future many more components inside the internal combustion engine will use ceramics in unique ways not possible until recently.

Social-Cultural Impacts

Ceramic materials are normally crystalline compounds of metallic and nonmetallic elements such as aluminum, iron, oxygen and silicon. Glass fits into the ceramic group, not due to its normal structure which is amorphous, but rather from elements found in glass and the similarity of properties possessed by glass match those of most other ceramics.

Next to wood, ceramics were humanity's first materials. In the form of common stone, ceramic was used in its natural state for tools and weapons. Eventually, people learned to improve upon natural rock and made arrow and spear points as well as cutting and digging implements. A clay pot found in Japan reveals that people had devised techniques to fashion cooking and eating utensils by working with clay at least 10,000 years ago. Sometime around 4000 B.C., Sumerian craftsmen learned to apply glazing to pottery to provide a glassy, non-porous surface on clay while allowing for decorative finishes. By 3000 B.C. Egyptians were making pots and vessels on potter's wheels. Around 600 A.D. the Chinese began making beautiful art objects of porcelain. The glazes applied to clay are a type of glass, so glass technology developed close to pottery technology.

By 1500 B.C. entire vessels were made of glass, the blow pipe for glassmaking came along around 30 B.C. and flat glass for windows was being produced by 50 A.D.; but plate glass, as we know it today, was not developed until 1688. Optical glass for eyeglasses, telescopes, etc. was developed about one hundred years later.

Steady, but not dramatic, improvements continued in ceramics up to the 1960s, then work in nuclear reactors spawned research and development efforts that brough new prominence to the ceramic industry. Today, ceramics are receiving attention from many areas in engineering. (*Scientific American*, 1967; Gordan, 1976; and McDermott, 1981.)

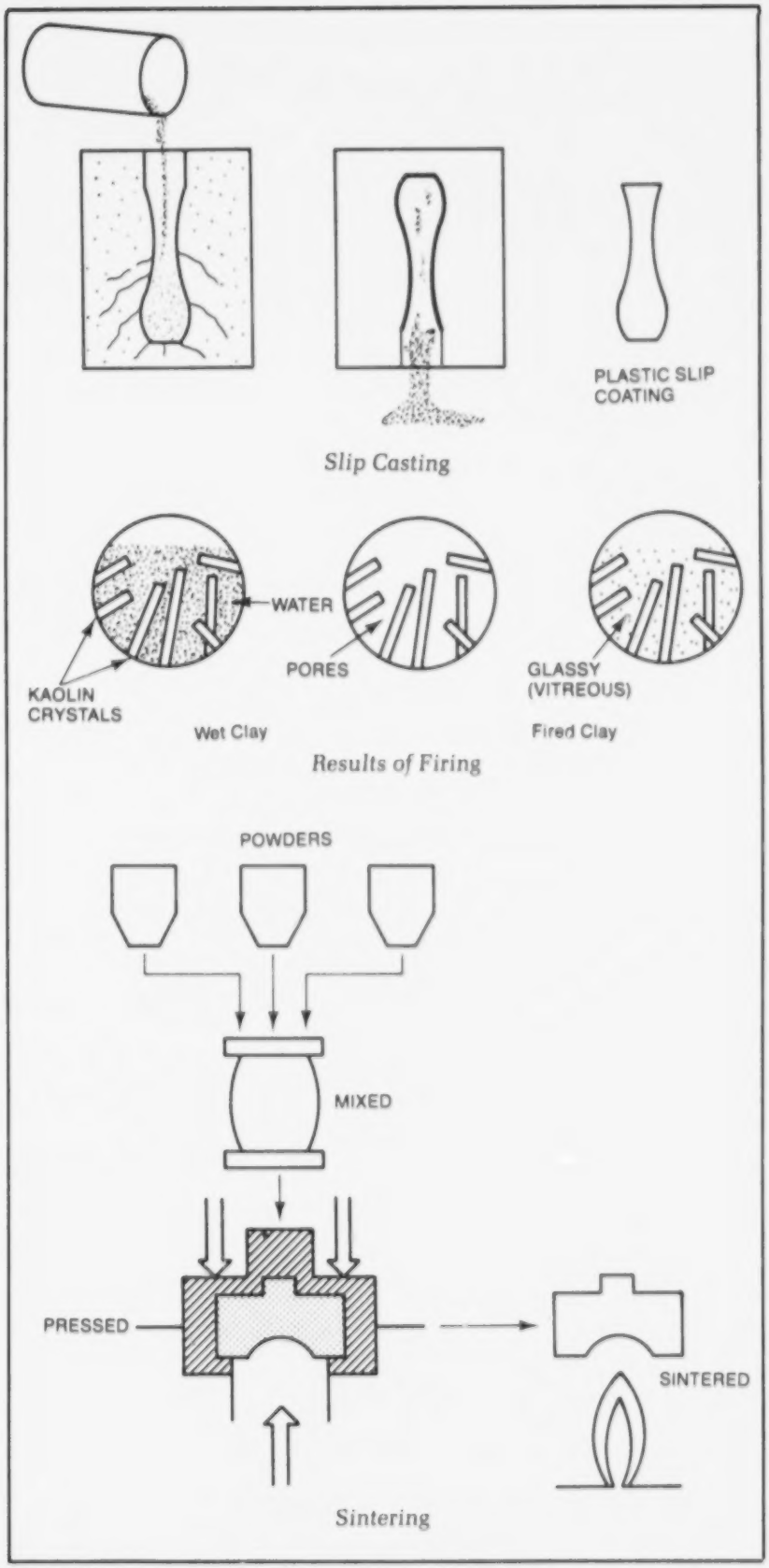


FIGURE 1

Selected ceramic processes.

Nature and Properties of Ceramics

Ceramic is a term derived from the Greek *kermos* meaning "burnt stuff." Please refer back to "New Materials" (TTT, 1985, May/June) for a basic definition of ceramics. Next, read the section on ceramic structure dealing with amorphous and crystalline structures and allotropes of carbon in "Nature and Properties of Engineering Materials," (TTT, 1985, December). With that background you can better grasp the concepts developed in this module.

Properties from Processing

Most ceramics are thermosetting materials, meaning once they have been processed and cured (hardened) they cannot be made soft and pliable again. Glass is the one exception; it is thermoplastic in nature with the ability to be continuously reheated and reshaped. Figure 1 depicts two common techniques for processing ceramics.

Slip casting (Figure 1a) involves pouring a slurry into a porous mold made of plaster of Paris. Slurry is a liquid, usually water, with ceramic particles.

In Figure 1a the slurry, known as slip, is poured into the mold; the water runs out pores leaving the soft ("plastic") clay that forms a shell next to the mold. The plastic clay casting, (greenware) is carefully removed from the mold and may receive some minor shaping by hand. The greenware is placed in a *kiln* and fired at temperatures around 1500°C (about 2740°F).

The results of firing are shown in Figure 1b in which greenware turns hard as some of the ceramic melts into a glassy (vitreous) state that binds the clay (Kaolin) crystals. The product of this type of firing is bisque, a hard porous material. Bisque may be coated with decorative *glazes* (glass) then refired to yield a nonporous final product.

Figure 1c depicts powdered metallurgy processing used on some cermets (ceramic metal) products. In this process fine particles of metals and ceramics are blended together; pressed into shape; then heated in a sintering operation.

Sintering is a firing operation in which parts are heated to temperatures below the melting point of most of the constituents in the mix, but high enough to

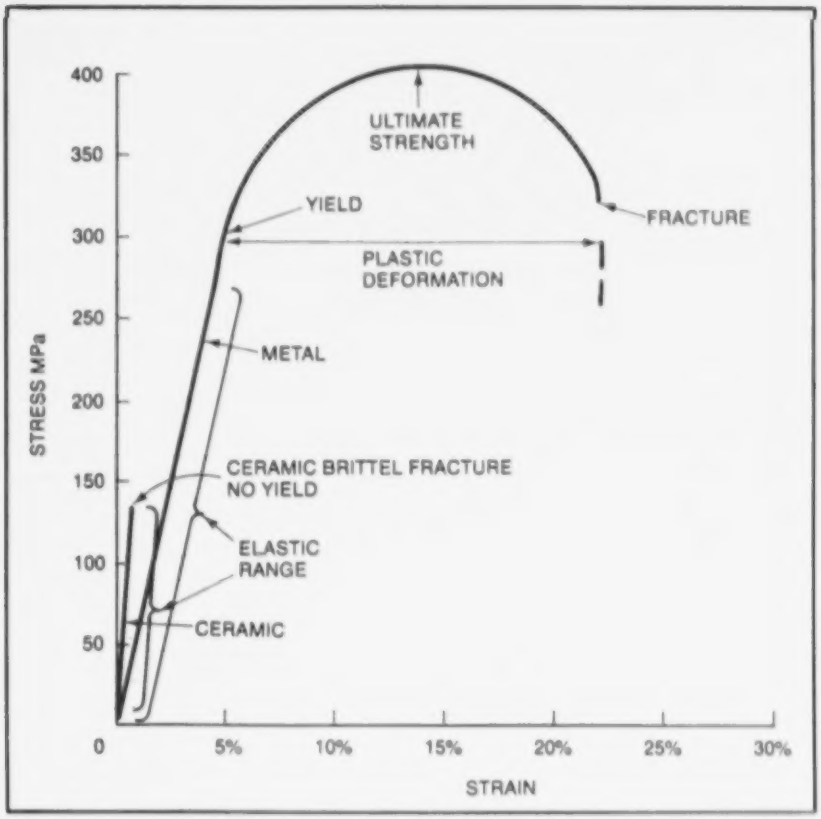


FIGURE 2

Stress/strain diagram comparing ceramics with a low carbon steel.

cause the particles to form cohesive bonds.

This is a very sketchy description of ceramic processing. More details are available in such references as Stafford's *Modern Industrial Ceramics* (1980). These three processes do illustrate major categories of processing that can be generalized to many other techniques for making ceramic products and aid in understanding ceramic properties.

Mechanical Properties

The stress/strain diagram (Figure 2) aids in seeing some mechanical properties unique to most ceramics. Recall the ductile and malleable nature of metals. Their ductility and malleability allows them to be stretched with tensile forces, squeezed with compressive forces, and bent with flexural forces.

The stress/strain diagram (Figure 2) was plotted as a result of conducting tensile tests on a specimen of metal and one of ceramic. The metal, in this case a low carbon and relatively soft steel, is pulled through its elastic range. In the elastic range, when the stress is removed, the material will return to its original length.

When stress is under 300 MPa (megapascals) the steel can elongate or strain about 4%, but will snap back with the load removed. With a tensile stress over 300 MPa, the steel yields and stretches beyond a point of return; it permanently deforms with plastic deformation. Continued increased tensile stress meets resistance and causes strain until the ultimate strength of the metal is reached at about 400 MPa. After the ultimate tensile strength point, less stress causes increased strain. With continuous but decreasing stress the metal elongates until it fractures (breaks).

Metals have an atomic crystal structure with densely packed atoms that allow the atoms to slide past each other for good ductility and malleability. Figure 2 provides a comparison of the tensile strength of ceramic with steel. Because ceramics have interrupted (less dense) packing of their atoms, they are not malleable and ductile and therefore cannot be stretched or bent for permanent deformation.

The curve plotted for the ceramic specimen tested in tension (Figure 2) reveals this stiffness. The ceramic specimen stretched (strained) less than 1% with about 140 MPa of force but did not yield, rather it broke when the elastic range was reached. Some glass can be bent through a rather sharp curve and return to its original shape. This is true of certain sheet glasses and optical fibers.

Ceramics are not only extremely stiff but are also hard and brittle. Instead of having equal bonding like metals, they have covalent, ionic, and secondary bonding of varying strengths. They fracture, instead of plastically deforming, due to this bonding since atomic packing is less dense. Trapped air bubbles that form during processing cause porosity and create points of stress concentrations where the failure occurs.

Electrical, Thermal, and Chemical Properties

The covalent and ionic bonding in ceramics make them good electrical and thermal insulators because their electrons are tied-up in bonding. This contrasts with metals which have free electrons in their metallic bonding systems. The free electrons are easily moved by an electromotive force (EMF) created by electric current. Metals also conduct heat well due to their bonding.

The Space Shuttle is covered with ceramic (silica) tiles to protect it from heat of friction generated by high speeds and re-entry to the earth's atmosphere. The tiles have very poor mechanical properties but their thermal insulating nature makes them valuable. The tiles create many problems for the Shuttle engineers and technicians (Jacobs & Kilduff, 1985).

These characteristics are not found in a single material. So a compromise must be made in selecting the necessary property while having to settle with certain undesirable properties as was done on the Space Shuttle tiles.

Why Ceramics?

One of the reasons for all the new found interest in ceramics lies in the raw materials of silicates: silicon (Si) and oxygen (O). Silicates are the most common and available mineral on earth. They include sand, clay, feldspar ($KAlSi_3O_8$), quartz (SiO_2), and the semi-precious gemstone garnet. As we look at the diminishing supply of raw materials for metals and oil for plastics, finding raw materials as plentiful as the sands of the deserts and oceans encourages the pursuit of ceramics as a prominent engi-

neering material beyond the year 2000. The ability to couple the abundance of raw materials with certain highly desirable properties makes ceramics truly an engineering material for the future.

The demands of technology create a need for higher performance materials. This means higher speed, hotter running engines, harder and more abrasion resistant materials, and other similar demands. For example, a push to machine harder metal at high speeds meant the development of exotic ceramic cutting tools such as the silicon nitride ($Si3N_4$) group of cermets.

The strong ionic bonding found in many ceramics makes them very chemical resistant. Glass, for example, will contain many strong acids and organic chemicals. Ceramics, in the form of bricks, blocks, and concrete, withstands outdoor weathering from ultraviolet rays from the sun, moisture, environmental pollutants, and dramatic temperature conditions. Other materials would corrode or decay under such conditions. Ceramics also can be used in extreme chemical environments in heat treating ovens, furnaces for making metals and glass, and in rocket engines. Such service conditions require resistance to heat, chemical corrosion, and erosion from moving liquids, solids, and gases.

The Ideal Engineering Material

An important point to remember about selection of engineering materials is that no material is perfect. Each material requires a compromise in its selection as with the Space Shuttle tiles. To be an ideal material it must have the following characteristics: (Jacobs & Kilduff, 1985, p. 4)

- Endless source of supply
- Cheap to refine and produce
- Energy efficient
- Strong, stiff, and dimensionally stable at all temperatures
- Lightweight
- Corrosion resistant
- No harmful effects on the environment
- Biodegradable
- Numerous secondary uses

Classifications and Applications

Difficulty arises in trying to classify ceramics because they are composed of many blends of inorganic (mineral or non animal/plant) and some organic (oil or hydrocarbon) elements. We will group them according to their applications and cover some of the common ceramics and some new and evolving ones.

Engineering and Technical Ceramics

Engineering ceramics covers those materials which are subject to stress such as in bearing heavy loads or reacting to tensile or flexural forces. They may be subjected to temperature extremes or corrosive environments, and must be processable so products can be engineered from them. They must be able to compete with the traditional engineering materials (wood, metal, or plastic) by having unique characteristics which give them a degree of superiority.

Technical ceramics may be considered a subgroup of engineering ceramics; but have distinct functions which may not necessarily involve the mechanical properties normally required for engineering materials. For example, technical ceramics include electronic materials such as silicon based semiconductors for the very large scale integrated circuits (VLSI) used to make computer microprocessors (Figure 3) or solar photovoltic cells.

Optical fibers are another subgroup of technical ceramics that have recently been the focus of considerable research and engineering. However, these glass fibers not only possess unique abilities to efficiently transmit light for voice and data communications, but have outstanding mechanical properties in terms of tensile and flexural strength. Figure 5 shows one process of making optical glass fibers beginning with a very pure silica glass tube which is heated till it collapses into a fiber.

Engineering ceramics are receiving a lot of attention for their possible use with internal combustion engines. A major objective in engine design is to obtain maximum energy output for energy input. Unfortunately, the conventional cast iron or aluminum block engine wastes up to 30% of input energy because the metals must be cooled and lubricated to avoid distortion resulting from the high heat involved in fuel combustion. A concerted effort is underway by engine manufacturers to eliminate water and air cooling systems with an engine known as an adiabatic engine.

Adiabatic engines function with a minimal transfer of heat from the combustion chamber into the block. Instead, the heat energy contributes to powering

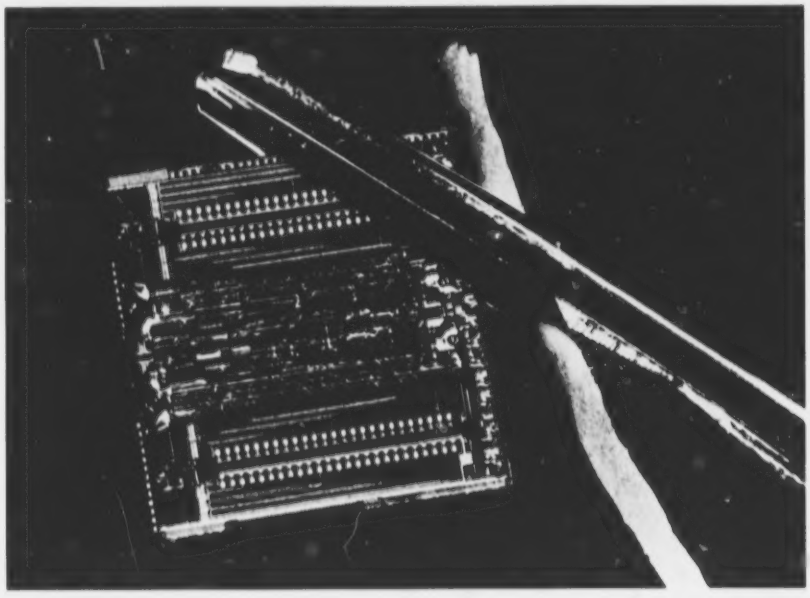


FIGURE 3

VLSI memory chip small enough to slip through the eye of a needle, but powerful enough to replace the rooms of vacuum tubes used in early computers.

FIGURE 4
Optical fiber manufactured from very pure silica glass tube.

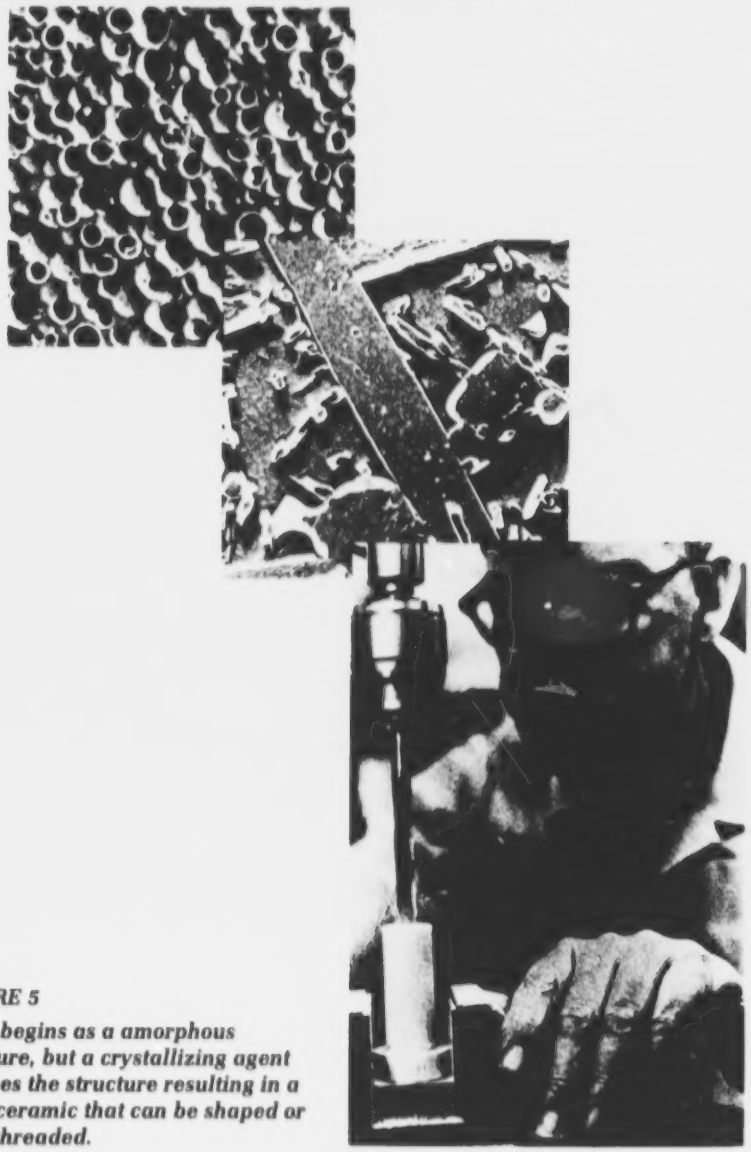


FIGURE 5

Glass begins as a amorphous structure, but a crystallizing agent changes the structure resulting in a glass ceramic that can be shaped or even threaded.

the engine. To reduce the heat transfer, ceramic liners are installed in strategic locations in the block to insulate the cast iron from the damaging heat.

In one type zirconia (zirconium oxide—$Zr\ O_2$) is used for the insulting liner. The sintered ceramic of partially stabilized zirconia (PSZ) has unique properties for this use. It has a coefficient of thermal expansion near that of cast iron. This means as the cast iron expands and contracts with temperature changes the PSZ will not separate at the interfaces. Mechanically, the PSZ has about 30% better toughness than most ceramic materials so it can withstand sudden impacts such as combustion shocks. Of course, its primary advantage comes through its thermal insulating property. (Jacobs & Kilduff, 1985).

Glass ceramics is another unique technical ceramic. We have said glass is an amorphous structured ceramic, whereas most other ceramics are crystalline. Glass ceramic begins as an amorphous glass such as beta cordierite ($2MgO{\cdot}2Al_2O_3 5SO_2$) or beta spodumene ($Li_2O{\cdot}Al_2O_3{\cdot}4SiO$). Through a heat treating process (Figure 5), an added crystallizing agent causes the amorphous structure to transform into a polycrystalline structure. Once in the polycrystalline state, the glass ceramic can be machined with ordinary tools.

Glass ceramics possess the thermal properties of other ceramics, but their ability to be machined is unique since most ceramics are too hard and brittle to receive much shaping after they have been fired or sintered. Glass ceramic can be threaded, cut into gears or similar shapes (Figure 5). (Jacobs & Kilduff, 1985).

Abrasives in the form of abrasive sheet (commonly called sandpaper), grinding wheels, and whetstones represent a familiar group of technical ceramics. They have properties common the majority of ceramics: very hard, brittle, and shatter upon impact. Materials used as abrasives include flint, emery, pumice (pulverized volcanic lava), rotten stone (shale rock), aluminum oxide, silicon carbide, and corundum. Diamond dust and synthetic diamond are the two most exotic abrasives and the hardest of all.

Refer to Figure 12 in "Nature and Properties of Engineering Materials," *TTT*, May/June, 1985 to compare the hardness of a select abrasive with other materials.

The key to abrasive selection is to insure that the ceramic is sufficiently

hard to abrade or wear down the material being processed. Beyond that are many other considerations that you can learn about from reading materials processing references.

Protective coatings are made by heating ceramics to a point of fusion that causes them to vitrify while bonding to a substrate (base material). Such coatings include decorative and protective glazes for pottery or porcelain coated metal as used for cooking, bathtubs, toilets and sinks. Industrial protective coatings may involve flame spraying a ceramic coating onto a metal substrate to give it heat and scratch resistant surface. A spark plug insulator is an aluminum oxide bisque substrate onto which a glaze has been fired to decorate it. The glaze also changes the porous nature of the bisque.

Ceramic magnets, thick and thin film ceramic substrate devices, nuclear fuels, refractories, fluxes, ceramic lubricants, and ceramic cutting tools are more technical ceramics that you might find interesting to study.

Cement and Concrete

Cement covers any material used to bond parts together.

Cementitious materials include ceramics such as pozzolans, lime, gypsum and masonry mortar and organic, nonceramics such as asphalt and a long list of natural and synthetic polymers. Portland cement is the major ceramic cement used in building and construction.

Portland cement consists of lime (CaO), silica (SiO_2), alumina (Al_2O), and iron oxide (FeO). The raw materials come from minerals in the earth and sea plus by-products of industrial processing. By varying the composition of Portland cement it is possible to develop five common cements with varying strengths and time required to set or cure.

Concrete is a composite of cement and aggregate such as rocks and sand which act as a reinforcer to the cement. The aggregates serve to transfer loads within the concrete as do other reinforcers such as steel rods and wire. Masonry mortar, a ceramic cement made from mixing Portland cements and other additives, is used for bonding together bricks, blocks, and similar building materials.

Glass

Glass products according to the American Society for Testing and Materials (ASTM), are those inorganic products of fusion that have cooled to a rigid condition without crystallizing. Glass comes in a very large variety of types with contrasting properties.

Most of us are familiar with the ordinary soda lime glass used to make window glazing, light bulbs, and drinking glasses. This low cost product is quite brittle and easily broken from mechanical shock or thermal shock. We know that a cold glass will shatter if a hot liquid is poured into it. However, glass made of 96% silica is very thermally hard, meaning it can withstand sudden temperature changes as seen in Figure 6.

Leaded glass of the crystal variety can be sculpted into beautiful works of art that bring collection items (Figure 7). The lead oxide refracts (bends) light much like gem crystals, but the glass crystal is amorphous, not crystalline, as the name implies.

Glass can be strengthened in a variety of ways ranging from heat treating, to chemical toughening, to reinforcing with steel wire or laminated plastic sheets.

It is possible to alter optical properties of glass so they become lenses for eyeglasses, microscopes and telescopes. Addition of silver ions will cause an internal reaction of optical glass structure so that bright light causes it to become shaded as with photochromic lenses. By laminating plastic film on window glazing, the windows reflect sunlight and allow efficient management of natural solar energy (Figure 8).

FIGURE 6

Bowl of 96% silica glass sits on block of ice as molten bronze (2000°F) is poured in.

FIGURE 7

Steuben rose of leaded "crystal" glass.

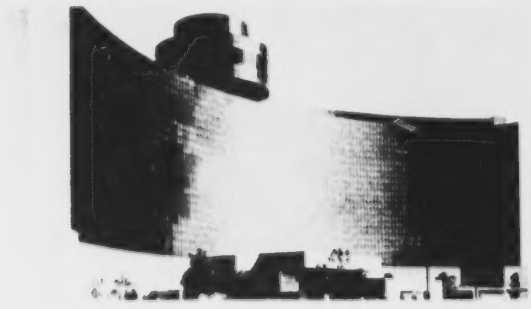


FIGURE 8

Solar shield: Reflective glass glazing forms a glass wall that reduces the entry of the sun's heat for cooling and energy savings.

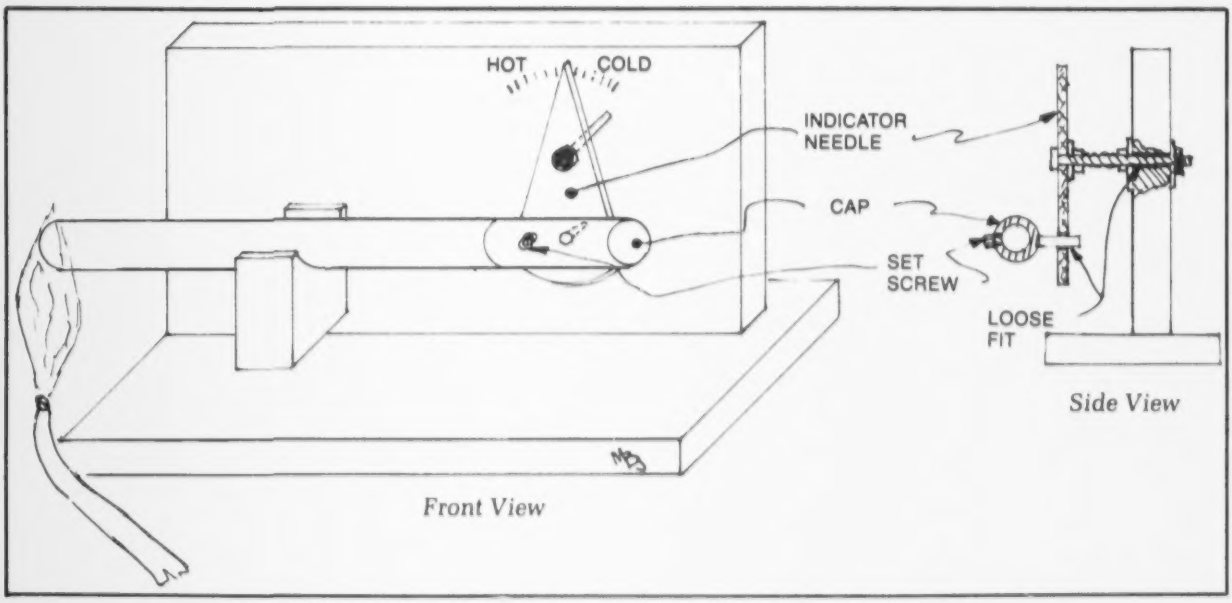


FIGURE 9
The testing device.

Construction Activity

In this instructional module we studied ceramics and pointed out that they have unique thermal properties. This construction activity will allow you to compare the thermal expansion of various materials. The next section will explain how to calculate the rate of expansion.

This testing device should be constructed mostly of wood for its insulating value. The indicator needle can be made of masonite and mounted to the vertical wooden member with a metal bolt using a loose fit. A hollow metal cap mounts over the specimens and is held by a set screw. A pin on the back of the cap fits loosely enough into the indicator needle to allow it to pivot and move the needle as the specimen expands and contracts (Figure 9).

Obtain rods of the same diameter and length of the following: steel, aluminum, brass, glass, wood, nylon, and any ceramic that might be available or made with clay (fired). Use a torch to heat the specimens and dry ice to cool it. Use a stop watch to insure equal time of exposure with torch and ice. Heat and cool each specimen three times, recording the readings from the scale on graph paper for comparison.

Math/Science/ Technology Interface

This module provided a glimpse at the rapidly developing field of ceramics. Thermal properties were mentioned as strong favorable properties for most ceramics. For example, the Thermal Protection System of the Space Shuttle Orbiter is made of silica because of its thermal insulating properties. We also mentioned the need for ceramic liners for cast iron adiabatic engines to possess a coefficient of linear thermal expansion close to the cast iron. Partially stabilized zirconia (PSZ) has such desirable thermal properties along with good mechanical properties.

Coefficient of linear thermal expansion (α) is the property that allows comparison of expansion and contraction of various materials. It provides designers with the ability to calculate how heat and cold will effect the sizes of materials. Figure 10 shows the coefficients of linear thermal expansion for five ceramics as well as for three nonceramics to provide a comparison.

MATERIAL	*RATE OF EXPANSION* (m/m/°C) 10^{-6}
Alumina	8.1
Beryllia	10.4
Silicon Carbide	4.3
Soda Lime Glass	9.4
Zirconia	6.6
Mild Steel	14.9
Aluminum	24
Nylon	90

m = meter C = Celsius

FIGURE 10
The co-efficients of the linear thermal expansion of eight materials.

EQUATION: $\Delta l = \alpha l \Delta T$	
ALUMINUM	SILICON CARBIDE
= (24 m/m/°C) (10^{-6}) (.020m) (15°C)	= (4.3m/m/°C) (10^{-6}) (0.20m) (15°C)
= (24 m/m/°C) (10^{-6}) (.020m) (15°C)	= (4.3m/m/°C) (10^{-6}) (.020m) (15°C)
= (24m) (10^{-6}) (0.20) (15)	= (4.3m) (10^{-6}) (0.20) (15)
= 7.2×10^{-6}m	= 1.29×10^{-6}

where α (Alpha) is the coefficient of linear thermal expansion
Δ (Delta) is change
Δl is change of length
ΔT is change in temperature

FIGURE 11

A comparison of the expansion rates of aluminum and silicon carbide.

Note that the ceramic materials have lower expansion rates than the other materials (except for beryllia which is close to that of steel). The ∝ for zirconia is not the same as PSZ which was altered to provide improved properties and have ∝ close to that of cast iron.

Which would expand more and by how much if a 20 mm rod of aluminum and silicon carbide were heated by 15°C? As Figure 11 shows, the aluminum rod would expand more than the silicon carbide rod by 5.91×10^{-6} ($7.2 \times 10^{-6} - 1.29 \times 10^{-6} = 5.91 \times 10^{-6}$).

Quiz

1. Name four examples how ceramics were used in early history. *(Many possible answers such as arrow and spear points, stone axes and cutting tools, pottery and brick).*
2. Name four examples of recent developments in ceramics. *(Many examples such as glass ceramics, cermets, nuclear fuel, siliccon nitride cutting tools, photochromic glass).*
3. Ceramics capable of bearing loads and competing with traditional materials such as steel, iron and wood are known as (engineering ceramics) .
4. Combinations of metals and ceramics that are sintered into finished products are called (cermets).
5. The composite material used in building construction that combines Portland cement with aggregate and other reinforcers is known as (concrete).
6. Arrange the terms in order to show the production stages ceramics go through from raw materials to finished products. a. bisque, b. slurry, c. glazed, d. greenware *(b, d, a, c).*
7. Name one characteristic of glass that makes it a) different and b) the same as other ceramics.
   (a) amorphous or transparent, thermoplastic; b) hard or brittle or ionic bonding, and many more).
8. What is a major reason ceramics are of great interest as we move into the year 2000?
   A good insulator of heat, abundant raw materials, etc.

Acknowledgements

Figures 1–10 from James A. Jacobs and Thomas F. Kilduff, *Engineering Materials Technology*, Reprinted by permission of Prentice-Hall Inc. Englewoods Cliff, NJ., 1985.

Figure 7 supplied by Corning Glass Works.

Figure 8 supplied by Pittsburgh Plate Glass.

Possible Student Outcomes

- Cite examples to show the historical development of ceramics from early times to the present.
- Explain why ceramics have taken on a new importance that has sparked research and development for improved ceramic materials and engineering techniques.
- Define the following terms and cite examples:

cermet	glaze
cement	vitreous
bisque	adiabatic
sintered	cementitious
elastic range	

- Draw stress/strain diagram curves for tensile specimen of a typical ceramic and a low carbon steel, and tell why the curves differ.
- Explain the requirement for compromise in selection of engineering materials as related to the idea of the ideal engineering material.
- Describe how ceramics develop their properties as a result of bonding and processing techniques.
- Explain the term engineering ceramics, cite examples of such ceramics and applications of each.
- Name the major groups of ceramics with examples for each.
- Calculate coefficient of linear thermal expansion for ceramics and other materials; conduct experiments to compare differences in rates of expansion.
- Develop an interest in the study of engineering materials technology to determine if you wish to pursue further study in one of numerous possible vocational and/or college programs.

References

Jacobs, J. A. and Kilduff, T. F. (1985). *Engineering materials technology*. Englewood Cliffs, NJ: Prentice-Hall, Inc.

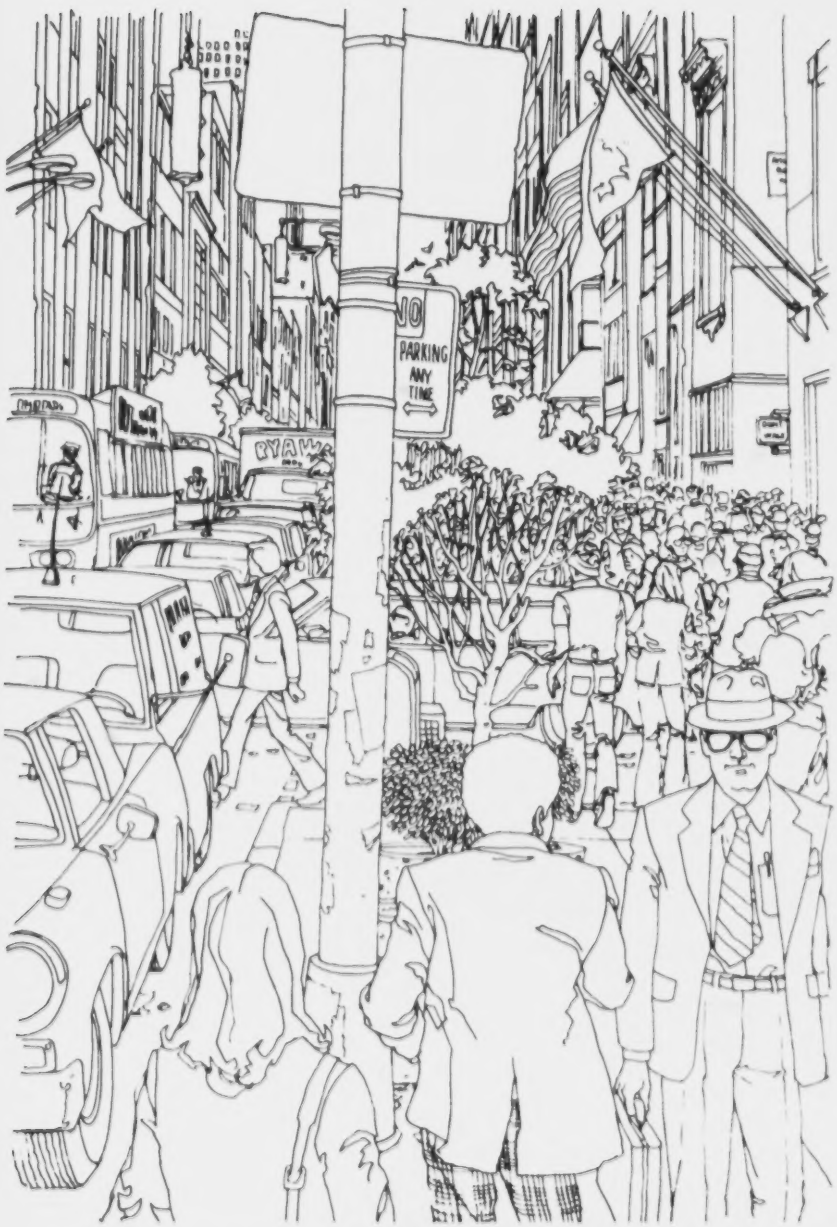
Materials. (1967, December). *Scientific American*. pp.

McDermott, J. (1981, November/December). Ceramics—the future beyond plastics. *Technology*. pp. 18–30.

Gordon, J. E. (1976). *The new science of strong materials or why you don't fall through the floor*. New York: Pelican Books.

Stafford, E. C. (1980). *Modern industrial ceramics*. New York: Bobbs-Merrill Educational Publishing.

Resources in Technology



Introduction

America's romance with the automobile has begun to turn sour. It has created almost as many problems as it has helped to solve. While the family or company car has provided a mobile and highly individualized means of transportation, it has also given society a myriad of unforeseen and thus, unplanned for, consequences.

The extensive use of this means of transportation has additionally excluded a large portion of our general population from its use because of the need for special training to operate a car and because of the costs involved in acquiring and maintaining it. These people have often been called the "automobile handicapped" and usually fall into one or more of the following groups: the young, the old, the poor, the physically and/or mentally impaired, and even those timid souls who will not drive and put their lives in jeopardy at the hands of other drivers (Gary, 1976, p. vii).

Other very significant detrimental effects have continued to escalate along with the growing numbers of cars. The pollution of air, noise, water runoff, and even our vision are but a part of the price society is having to pay for the convenience of the automobile (Anderson, 1972, pp. 1–2). Another obvious and grim statistic has also continued to grow along with the proliferation of the automobile. The death and disability caused on our nation's overcrowded streets and highways is an all too common factor in our daily lives.

There must be a better way. There is.

PRT: The Way To Go!

Personal Rapid Transit (PRT). The name sounds simple enough. In fact, it is. It may be the answer to many of our problems, at least in our cities and urban areas. It's personal, which is defined by Merriam-Webster's dictionary as "... affecting a person, relating to a body or person." It is also rapid or, as Webster says, "... very fast." Transit, as used here, is described by the same dictionary as the "... local transportation, especially of people by public conveyance." Indeed, PRT is a combination of all these various definitions—and more.

A more descriptive and technically accurate assessment of just what PRT is (or could be) was given at the 1975 International Conference on Personal Rapid Transit. The conference committee stated that in a PRT system relatively small, automated vehicles move people and/or goods between stations in a network of separate, dedicated, slim guideways which serve major activity areas, or entire urban areas (Gary, 1976, p. v). PRT systems may use vehicles which are suspended (or hanging) from above or they may travel on surface or elevated rails. The movement of passengers from one airline terminal to another at some of our busiest airports is one of the best known applications of the PRT method of people moving.

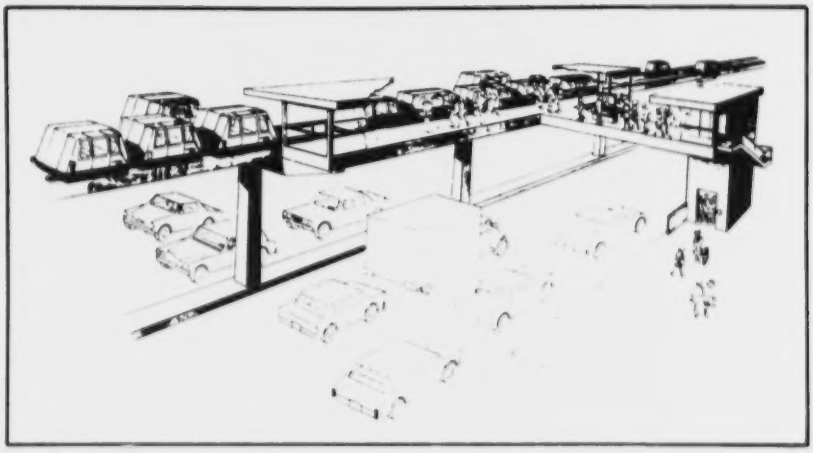
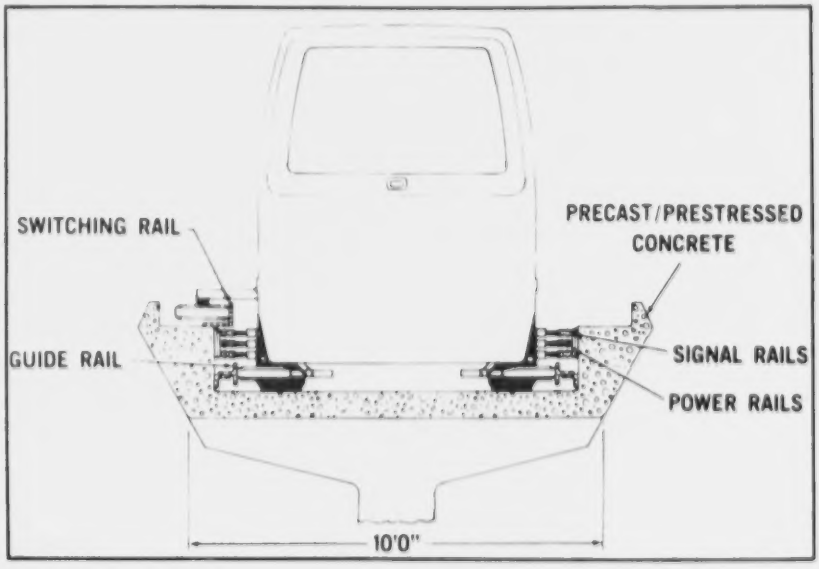


FIGURE 1
A Typical PRT System

PRT systems are also being used more frequently to move people more conveniently at many of our country's increasingly popular theme parks. Some discussion among farsighted planners has even considered the feasibility of such systems at some of our most heavily visited national parks. Let's look now at how this unique transit concept has developed and continues to grow.

FIGURE 2
PRT Guideway Cross Section



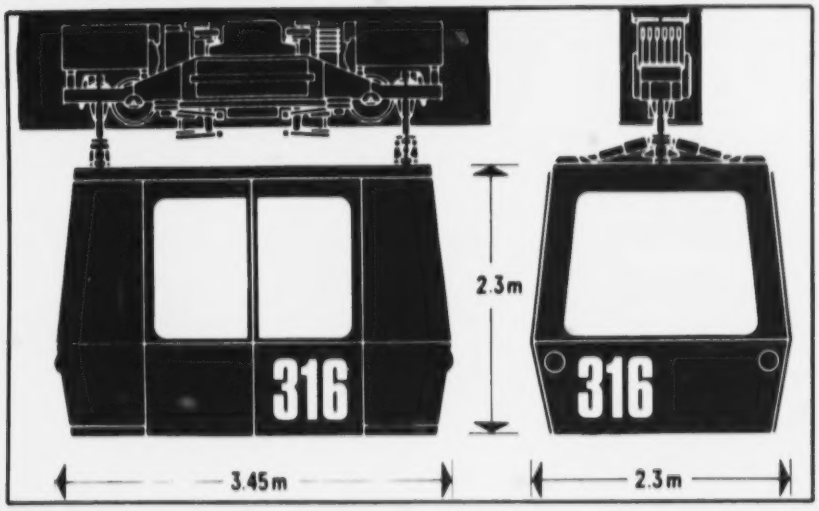


FIGURE 3
Running Gear of a Suspended PRT System

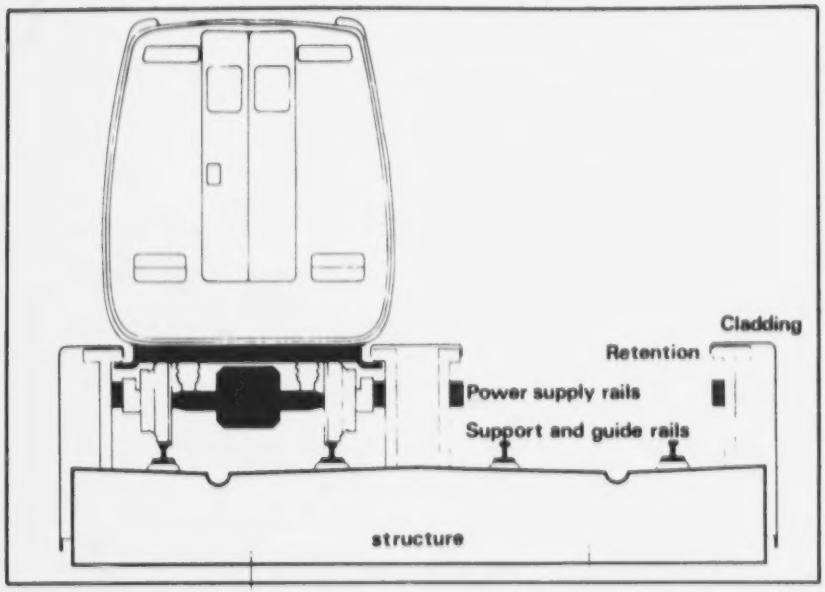


FIGURE 4
A Wheeled PRT Vehicle and Guideway

Contemporary Analysis

Earlier forms of transit grew from the application of an already existing or developing technology to urban transportation problems. Streetcars and subways were developed by combining the technology involved in railroad vehicles with steel wheels with that of electric motors. Buses and automobiles were an outgrowth of the applied technology of internal combustion engines. Similarly, PRT's development can initially be drawn from the new technologies of automation, computers, new materials and processes, and be integrated with older technologies to provide the most beneficial and cost-effective outcomes.

While the development of PRT has many similarities to the development of other existing transit forms, it differs in at least two major ways. First (and of great significance) is the enormous volume of technology available to apply to the problem. Because only the end result of PRT has really been defined, any innovative approach may be feasible.

Presently, technology has not stated that "A plus B must equal C." Any equation (or combination of technologies) will be accepted by society as long as the end product, a PRT system which fits the accepted definition in all respects, is the result.

Secondly, the philosophical approach to the solution of designing, developing, and implementing a workable PRT system is vastly different from that of earlier transportation systems. A new and higher priority seems to be involved in the development of PRT. It is viewed as the ideal transit system for urban areas, not just as a "good one." Such an ideal transit system could solve very many of our cities' transportation problems, at the very least for a very long time.

Because of this overriding philosophical belief, innovators (sources of ideas, developments, etc.) do not simply view PRT as a technological challenge to be solved by applying old technology to new concepts or vice-versa, but as a systematic approach to a very complex problem. It is believed that this approach will ultimately lead to an acceptable and extensively implemented PRT system. (Gary, 1976, pp. vii–viii).

Although the development of PRT systems is a contemporary problem, the search for such systems is not new.

In one of the first urban public transportation services in the United States,

Abraham Brewer put a horse in front of an open coach in 1827. In 1939, General Motors had an automated highway system under development. During the 1960's William Alden was also at work, attempting to use his expertise in the industrial application of automation. Others have also been at work.

The U.S. Congress developed a series of studies which gave impetus to many of the innovative efforts in PRT development. These Housing and Urban Development studies focused on the development of a PRT system that would satisfy a service concept. The studies ultimately resulted in the 1968 report, *Tomorrow's Transportation*.

As the PRT concept has evolved, it has done so mainly because of the public's major expectations of public transit. For such a system to be used, it must be accepted and patronized by the general public. No system, no matter how well designed, will ever be successfully operated without such acceptance. Some of the requirements placed on such a system are:

1. The system must meet the needs of those individuals who have no personal means of transportation.
2. The service provided must be attractive enough to cause potential automobile drivers to use it and, thus, help eliminate the continual need for road improvements in urbanized areas.
3. The system must effectively reduce congestion.
4. It must be safe.
5. It should reduce travel time.
6. The system should make economic settlement patterns more feasible.
7. A properly designed system should make a significant contribution to the reduction of energy consumption.
8. For the most part, citizens in areas served should have their needs for a second car eliminated.
9. It should permit a reduction in noise pollution.
10. An acceptable system should reduce the burden of material resources required for urban transportation.

There are other requirements such as financial constraints, degree of land use, and the elimination of the pollution caused by internal combustion engines to name only a few (Gary, 1976, pp. 1–2).

With these criteria in mind, several locations for PRT systems are immediately obvious. Today many of our urban activity centers are served primarily by automobile. The parking lot at a rock concert or a professional football game are cases in point. Beyond a certain size, activity centers such as malls, shopping centers, sports centers, airports, other transportation centers, downtown urban areas, etc., are not at all well served by the family car.

PRT could be the answer.

Many experts in various fields believe it is.

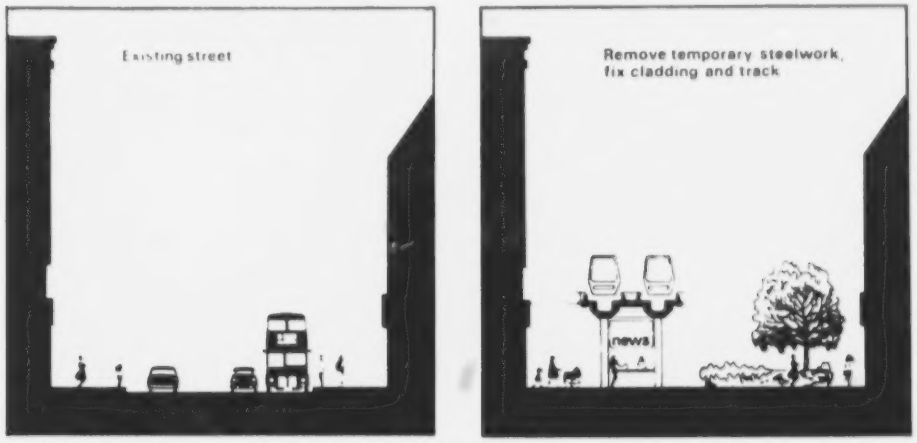
Using the same criteria as a guide, further outward development of a city's economic areas (malls, recreational areas, shopping centers, etc.) would seem to be a natural consequence and a very desirable one. It is also the nature of man to live in groups; hence, the suburbs. A PRT system which effectively served suburbanites in their transportation needs regarding work, shopping, schools, and leisure would be beneficial to both the individual and the community.

Cost factors are, of course, a limiting factor in the placement of PRT systems (Anderson, 1972, pp. 207–222). It may be impossible to ever build an economically feasible PRT system into an already existing crowded urban center. Still, proposals have been made for many large cities and have been implemented in still others. For the most part, though, cost-benefit ratios do not favor such systems in many areas. Rural settings also do not usually favor PRT systems.

New economic or suburban areas could be and are being designed to facilitate the present or future incorporation of PRT systems, however. By avoiding the planning (or lack of it) mistakes of the past, PRT may well be located in almost any new activity center. Obviously, land use planning is an essential prerequisite for the large scale deployment of PRT systems.

Once PRT has proven itself to be acceptable to the needs and tastes of the public in limited ways such as in the application already discussed, it may then be practical to consider placement in many of the areas previously thought to be "beyond help."

FIGURE 5
An Urban Street Before and After PRT Installation



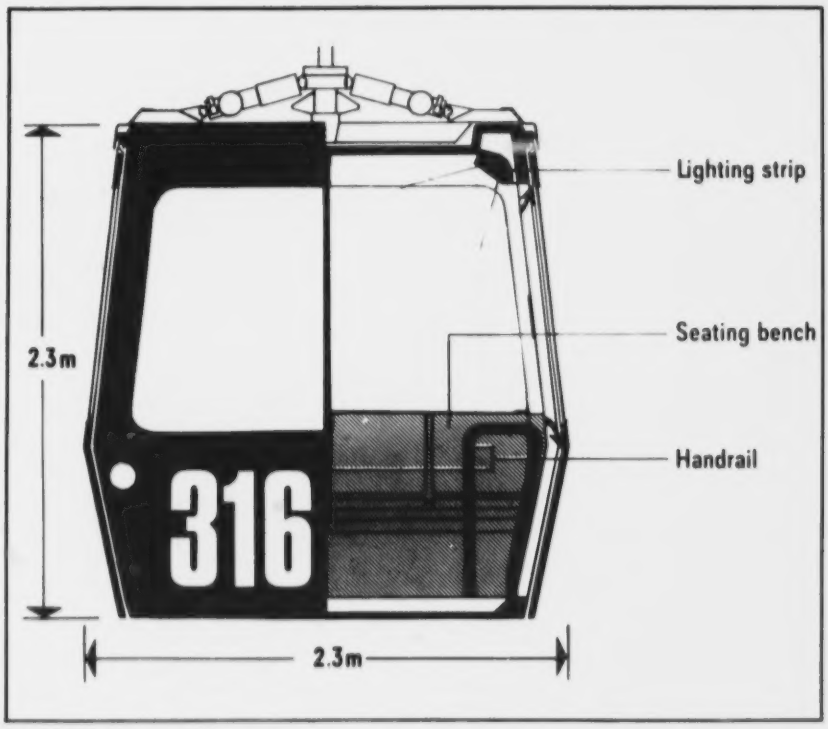


FIGURE 6
Cutaway View of a PRT Vehicle

The Future

The relatively small number of PRT installations in use today are not nearly enough for planners to assess its true value and benefit to society. Initially, the cost in dollars may seem to be quite high, but in the long run the cost-benefit ratio may prove to be highly favorable. One major factor that should prove to be decisive will be the innovator's ability to provide the required technology at a cost advantage over the family car (Gary, 1976, p. 106).

Traditionally, research and development for endeavors such as PRT have been most successful in private firms, free of governments constraints and meddling. Until recently, government money for such research was limited anyway and still is to some degree. One distinct advantage to limited governmental involvement is the lack of political pressure. At times, such pressure may produce unrealistic deadlines and/or cause less than the best results to emerge.

Initial start-ups of almost any new technological system have problems, predictably. This is not to the detriment of PRT development, but should serve as a spring board from which designers and developers can learn. Proper assessment of any problems can many times preclude their re-occurrance in new systems. The lessons learned from the Morgantown (W. Va.) system and the Airtrans installation have been most beneficial to other developments. Insights have been gained from many other similar installations.

In many urban and other settings, PRT is still just a gleam in the eyes of some lone planner. It is all too easy for others to get caught up in making design changes or refinements to traditional systems. That will not solve our transportation problems. PRT may not either, but it will go a long way toward reaching that elusive goal. The next section will focus on the mathematical, scientific, and technological interface involved in PRT. To better understand the aspects of this interface and how PRT technologies may operate to change our lives, one must have a clear perception of its principles.

M/S/T Interface

One factor greatly contributing to the economically desirable features of PRT can be illustrated mathematically when we consider the following example of a proposed shopping mall.

Enclosed shopping malls or centers are quite commonplace now and are almost always a part of any new suburban setting's development. Two of the major attractive features of such a mall are the elimination of the family car in front of every store and the ability of pedestrians to shop and move about at will, oblivious to weather and traffic.

As is the case in most shopping centers, our example features a group of enclosed stores. Initially, the center was to be surrounded by a mammoth parking lot. It was calculated that each space in the lot could be expected to generate between $10,000 and $12,000 of revenue each year. However, later the planners determined that the use of the immediately surrounding land for a parking lot might not be as economically satisfactory as utilizing cheaper nearby land for remote parking.

With the remote parking served by a small PRT system, the more desirable land formerly designated for the surrounding parking lot could be developed for apartments, offices, or other suitable businesses. Stations for the PRT system could be located at the remote parking lot and near the new developments as well as inside the mall.

Let's look at some figures and determine for ourselves just what the advantages or disadvantages of various parking options might be. For our example, we'll consider the parking costs involved in three different locations. These are:

1. Surface parking in a remote location
2. Surface parking in the mall area
3. Utilization of a parking garage.

In the accompanying table (Table 1), the figures clearly indicate that from $20 to $34 million could be saved by using the remote parking option. Additionally, when the value of the shopping center is considered after the land immediately around it is developed, it may increase two or three times. The costs, then, of installing a PRT system to serve the remote parking facility could be easily justified.

Similar calculations are used to estimate the cost-benefit ratio of any PRT system, although many other variables may be considered.

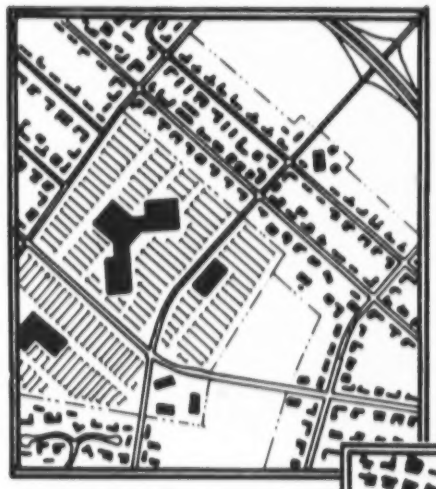


FIGURE 7
A Shopping Center With Surrounding Parking

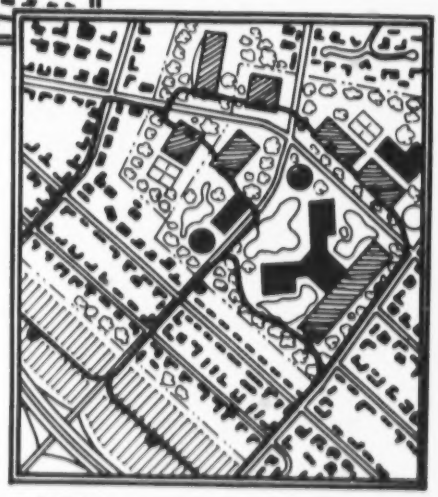


FIGURE 8
The Same Shopping Center With Remote Parking

	Surface Parking (Remote)	Surface Parking (Mall)	Parking Garage
Land for 7,000 Spaces	270,000m²	270,000m²	75,100m²
Price/m²	$55/m²	$130/m²	$350/m²
Total Land Cost	$14,850,000	$35,100,000	$26,285,000
Structure Surfacing Cost	$22/m²	$22/m²	$110/m²
Total Surfacing Cost	$154,000	$154,000	$770,000
Total Improvement Cost	$6,000,000	$6,000,000	$28,000,000
Total Cost	$21,000,000	$41,240,000	$55,055,000

TABLE 1
Cost Analysis of Parking Alternatives

Construction Activity

One of the major problems confronting city planners and traffic engineers is that of getting shoppers to and from commercial activity centers with a minimum of cost and inconvenience. Public acceptance of any PRT or other system is highly dependent on these two factors. Further, any system that meets these two primary requirements must also meet those of safety, speed, comfort, and others.

The focus of this constructional activity will be to use laboratory tools and materials (wood, glue, cardboard, metal, or others) to design and construct an efficient and acceptable PRT system for a location in your area. It must incorporate the design features believed by your class to be most appropriate and advantageous a local system.

A city street map and class members' local travel experiences would seem to be a logical starting point. Do class members agree or disagree? Why or why not?

The accompanying project diagram (Table 2) gives a graphic representation of the parameters of this activity/problem. The class may wish to re-organize the diagram to better suit its needs. While costs must necessarily be considered, do not let them be a determining factor.

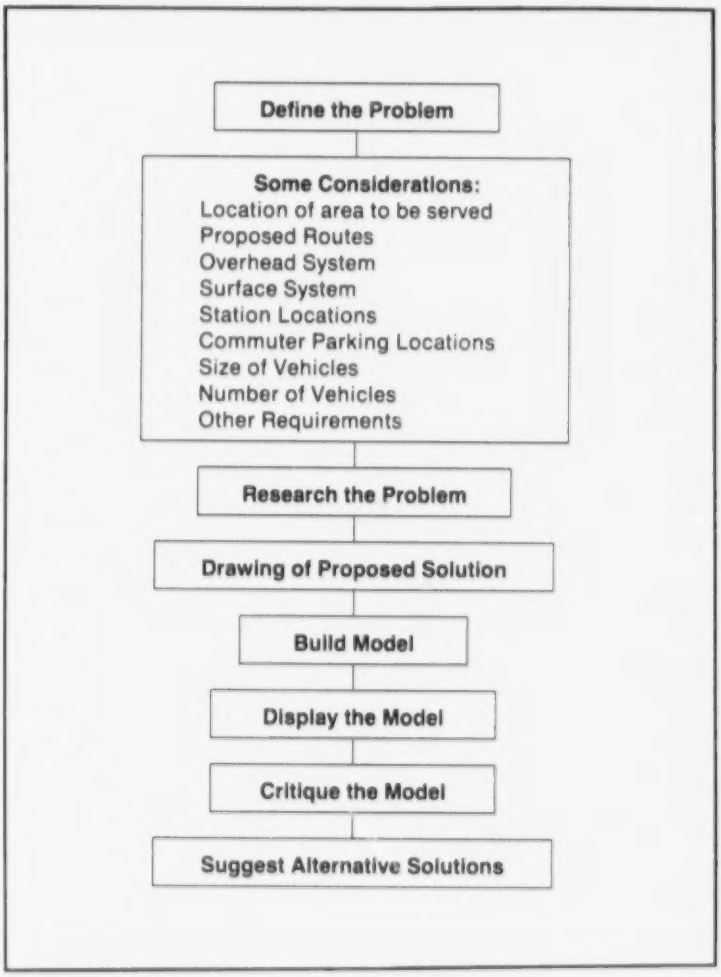


TABLE 2
Project diagram

Research Criteria

A. Congested areas requiring service
B. Suggested routes
C. Overhead or ground level system
D. Station locations
E. Automobile parking locations for remote lots
F. Size and number of vehicles
G. Other requirements

Suggested Solutions

A. Overhead PRT with space below for small shops, streets, walks, parks, etc.
B. Parking at existing outlying area lots
C. Small PRT vehicles
D. Available power source

Build Model

Using tools and materials located in a technology lab, build a model of a proposed PRT system for a local area requiring such service. Your model should approximate actual scale as nearly as is practical.

Class Display

Have each student write a one-to-two page detailed report on the model, highlighting those portions each participated in. Defend the solution and explain the rationale for various design features. Several class members should be selected to present their reports orally, pointing out features on the model.

Results

Bring in a knowledgeable outside speaker (city traffic engineer, PRT person, etc.) to critique the class model. Have the speaker discuss the critique with the class if possible.

Summary

This constructional activity clearly illustrates the important role that technology (industrial arts) programs can play in contemporary society. An awareness of the technological challenges of our present and future needs can be greatly enhanced by this and similar activities.

Quiz

After presentation of this material or after the class project work is completed, use a simple multiple-choice type quiz such as the sample below to check for student understanding. You may wish to also use this as a pretest.

1. The present use of PRT systems at major activity centers is
   A. non-existant
   B. limited
   C. not a desirable feature
   D. not cost effective
2. Persons in the following group are often among the "automobile handicapped."
   A. commuters
   B. the aged
   C. rail travelers
   D. non-frequent drivers
3. PRT systems may utilize
   A. slim guideways
   B. automated vehicles
   C. overhead rails
   D. all of the above
4. The extensive use of automobiles may cause the following kind of pollution
   A. noise
   B. vision
   C. air
   D. all of the above
5. One positive factor contributing to the development of PRT is
   A. existence of high-speed monorails
   B. work ethic of society
   C. the enormous volume of technology available
   D. growth of rural areas
6. Development of PRT systems has evolved over a period of how many years?
   A. 10
   B. 25
   C. 43
   D. 100 plus
7. The PRT concept has evolved mainly because of
   A. one dedicated innovator, Abraham Brower
   B. the public's major expectations of public transit
   C. free flowing federal funds
   D. cooperation of local, state, and federal authorities
8. A properly designed PRT system must not
   A. meet the needs of individuals with no personal transit
   B. encourage automobile drivers to use it
   C. help eliminate the need for continual road improvements
   D. effectively create congestion
9. Citizens living in areas served by PRTs should not
   A. need a second car
   B. mind walking once in a while
   C. expect any reduction in noise pollution
   D. expect a reduction in the urban transit materials requirement
10. Locations where PRT systems might prove to be least beneficial and least cost-effective are
    A. shopping centers
    B. recreational areas
    C. rural areas
    D. newly-developing economic areas
11. Initial startups of new technological systems
    A. may expect problems
    B. may expect no problems
    C. are very rare with today's technology
    D. began about 10 years ago
12. Traditionally, research and development for endeavors such as PRT have been most successful
    A. in outlying areas
    B. under federal controls only
    C. under state and federal controls
    D. in the private sector
13. The relatively small number of PRT applications in use today
    A. have doomed further development to failure
    B. make it impossible to assess its benefits to society
    C. indicates public rejection of the technology
    D. indicates more urban centers in the future
14. In PRT design and development, the cost-benefit ratio should
    A. favor PRT
    B. be inconsequencial
    C. seldom be considered
    D. be calculated after the system's implementation
15. Mistakes involved in the planning of past urban transit projects
    A. are best forgotten
    B. were mainly accidental and/or due to carelessness
    C. should help new PRT development
    D. should be repeated under strictly controlled conditions

Possible Student Outcomes

- Define Personal Rapid Transit (PRT)
- Differentiate between PRT and mass transit.
- List the benefits of a properly designed PRT system.
- Analyze the effects of PRT on a shopping or sports center.
- Contrast the use of PRT and the automobile.
- Apply knowledge and materials to the solutions of technological problems.
- Associate math and science as an integral part of the study of the technology of PRTs.

Selected Readings

Conference Proceedings (May 31–June 2). (1972) Intersociety Conference on Transportation: Washington, DC.

United States Office of Technology Assessment. (1975) *Automated guideway transit. An assessment of PRT and other new systems.* Washington, DC: Government Printing Office.

New and novel transportation systems (Special Report). (1970) Institute of Transportation and Traffic Engineering: University of California.

References

Anderson, J. E., et al. (1972). *Personal rapid transit.* Minneapolis: University of Minnesota.

Gary, Dennis A., et al. (1976). *Personal rapid transit III.* Minneapolis: University of Minnesota.

Acknowledgements

All figures have been taken from *Personal Rapid Transit III*, Dennis A. Gary, General Editor, and are used with permission.

1987-88
Board of Directors

President
M. James Bensen

President-Elect
Jane M. Smink

Past President
W. David Greer

Director, Region 1
William J. Boudreau

Director, Region 2
Ronald D. Yuill, DTE

Director, Region 3
Bruce Barnes

Director, Region 4
Merrill M. Oaks, DTE

Director, CS
Thomas LaClair

Director, CTEA
Jack Kirby

Director, CTTE
Donald P. Lauda, DTE

Director, TECA
Arvid Van Dyke

Director, TECC
Roger A. Schaefer

Executive Director
Kendall N. Starkweather

INTERNATIONAL TECHNOLOGY EDUCATION ASSOCIATION
1914 ASSOCIATION DRIVE
RESTON, VA 22091-1502